A Summary of Current Program 7/1/64 and Preliminary Report of Progress for 7/1/63 to 6/30/64

ENTOMOLOGY RESEARCH DIVISION

of the

U. S. AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

and related work of the

STATE AGRICULTURAL EXPERIMENT STATIONS

Section A

This progress report is primarily a tool for use of scientists and administrators in program coordination, development, and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on USDA and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of USDA and cooperative research issued between July 1, 1963, and June 30, 1964. Current agricultural research findings are also published in the monthly USDA publication, Agricultural Research. This progress report was compiled in the Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Md.

UNITED STATES DEPARTMENT OF AGRICULTURE

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INTRODUCTION

Entomology research is concerned with both destructive and beneficial insects in relation to the growing of fruits, vegetables, forage, grain, cotton, tobacco, sugarcane, sugarbeets, and ornamental crops; the management of bees in relation to pollination and honey production; and the production of all classes of livestock and poultry. In addition, it includes investigations on insects affecting man, households, and industrial establishments; the identification and classification of insects; the biological control of weeds; and on chemicals including insecticide residues on all raw agricultural commodities derived from crops and livestock.

Insects (including ticks and mites) constitute the largest class of animals. Approximately 85,000 kinds occur in the United States, of which 10,000 are regarded to be of economic significance. Insects are both destructive and useful. They are man's greatest competitor for food and fiber, and at the same time they are vital to man's existence. Without honey bees and other insect pollinators, many important crops could not be grown, and without the insect parasites and predators, which help to maintain a reasonable balance between harmful and beneficial species, destructive insects would increase to such numbers that it would almost be impossible to control many of them even with our best control measures.

All crops in every stage of growth are subject to attack by insects. Seeds placed in the ground may be destroyed before or during sprouting. Growing plants have their roots, stems, leaves, or fruit damaged by many kinds of chewing and sucking insects. Livestock are infested by numerous insects, ticks, and mites. Insects are important in that they cause annoyance and losses due to direct feeding and also because they are responsible for the spread of many of the most serious diseases affecting plants, animals, and man. Thus, it is understandable why insects exact a toll of the Nation's resources estimated at 4 billion dollars annually.

Outstanding progress has been made in the development of control methods for most of the major insect pests, by developing chemical, cultural, biological, and genetic control procedures. Of these various procedures, chemical control methods are now employed to meet about 90 percent of our insect problems. However, the use of insecticides has led to many problems that are of growing concern to the public, such as residues in foods, and adverse effects to fish and wildlife, beneficial insects, and other organisms in the treated environment. Because of such problems major shifts in emphasis have been made in the entomology research program to strengthen research on biological control methods, the development of plant varieties resistant to insect attack, attractants and baits to provide specific methods of control for certain insects, and the exploration of other new approaches such as the use of sterile insects for their own destruction. All of these methods offer excellent possibilities for improving insect control and eradication procedures.

The Entomology Research Division has work located at 62 field locations in the United States, 5 locations in foreign countries, and one in Puerto Rico. Of the total professional staff of 430, 111 are located at the Agricultural Research Center, Beltsville, Md., or at Washington, D. C. The Division and the Branch leadership staffs responsible for the administration of research programs throughout the country and abroad are headquartered at Beltsville, Md. Two Pioneering Laboratories, one on Insect Pathology and the other on Insect Physiology, both devoted to basic research, are also located at Beltsville. In addition, basic research is conducted by entomologists and chemists at Beltsville, in cooperation with scientists of other disciplines. Insect identification research is conducted in Washington in close collaboration with the Smithsonian Institution.

The personnel at field locations cooperate closely with State Experiment Station and university scientists. There is also close cooperation with trade associations, industrial establishments, health agencies, and growers. Most of the applied research is conducted at the field locations and such research will continue; however, more and more attention is being given to basic investigations pointing to better long-range solutions to insect problems of national significance.

Cooperation is also maintained with other research divisions in the Agricultural Research Service and with divisions of the Service concerned with plant and animal pest-control and plant and animal quarantine programs. There is also cooperation with other research and regulatory divisions in the Department of Agriculture and with other agencies including the Department of Defense, Department of Health, Education and Welfare, Department of Interior, World Health Organization, and Agency for International Development.

The Division sponsors 44 research projects in 12 foreign countries financed under the Public Law 480 program for utilizing foreign currencies received in payment for excess agricultural products from the United States. Research on the biology, ecology, and sterilization of the tsetse fly is conducted in Southern Rhodesia, Africa, under an agreement with the Agency for International Development and in cooperation with the Agricultural Research Council of the Federation of Rhodesia and Nyasaland.

A broad analysis of the Division's research by different approaches to insect control shows that about 28 percent of the current effort is on the conventional chemical approach to insect control; 15 percent on biological control (parasites, predators, and pathogens); 6 percent on plant resistance to insects; 19 percent on the sterility and other new approaches to insect control such as natural attractants; and 32 percent on other entomology research including basic biology, physiology, taxonomy, apiculture, and insect vectors of diseases. Substantial changes in the research effort have been made in the last 6 years, largely by shifts within available funds, to place more emphasis on nonchemical or on special chemical approaches to insect control.

A Metabolism and Radiation Research Laboratory was established in FY 1963 at Fargo, North Dakota, to provide for research on the metabolism of insecticides in insects, plants, and animals by Entomology, Crops, and Animal Husbandry Research Divisions and for intensifying research of the Entomology Research Division on the sterility approach to insect control. Equipping and initial staffing is under way.

The following examples of outstanding achievements in research by scientists in the Entomology Research Division illustrate the value of entomological research in the improvement of the Nation's agricultural economy and general welfare of the people:

Biological control of alligatorweed by introduced insect. Alligatorweed, native to South America, became established in the United States about 100 years ago and has become a serious problem in the Southeastern States where it clogs waterways and other inland streams. A flea beetle that confines its attack to this weed and, therefore, is not a threat to crops or other plants, was discovered in Argentina and imported into the United States. Colonies have been released in South Carolina and distribution will be made soon to other alligatorweed-infested areas. Successful suppression of this weed by the flea beetle is expected to reduce the need for use of herbicides to control this plant.

Releases of sterile Mexican fruit flies eliminate need for insecticide spray. Applications of bait sprays have been relied on since 1955 to suppress the Mexican fruit fly in Northwestern Mexico, where it periodically appears when infested fruits are brought in from further south. Protective sprays have also been applied to certain threatened areas along the border in California. Weekly releases of thousands of sterile male fruit flies to mate with wild female flies, thereby preventing fertilization and establishment of infestations, eliminated the need for the costly and annoying spray programs previously conducted in northern Baja California and southern California. The released flies were produced and sterilized with tepa at the Mexico City laboratory where special techniques were developed for mass rearing, sterilization, and transportation. They were shipped by air to Los Angeles for distribution in Baja California by the Plant Pest Control Division in cooperation with the Mexican Direccion de Defensa Agricola. This was the first practical use of sterilized insects to prevent establishment of introduced pests.

Parasitic wasps introduced for control of the cereal leaf beetle. One of three species of parasitic wasps that apparently aid in the control of the cereal leaf beetle in France and Italy has been imported into the United States. In cooperation with the Agricultural Experiment Stations of Michigan State and Purdue Universities, colonies of the parasite have been released in Indiana. The parasites immediately attacked cereal leaf beetle larvae.

Tobacco hornworm populations suppressed in large scale blacklight trap experiments. Tobacco hornworm populations were reduced about 60% in 1962 and about 83% in 1963 in a community-wide blacklight trap installation in a flue-cured tobacco area near Oxford, North Carolina. This large scale experiment, conducted in cooperation with the Agricultural Engineering Research Division and the Agricultural Experiment Station of the University of North Carolina, embraced an area of 113 square miles with 3 lights per square mile. An intensified stalk cutting program in the fall of 1962 in the experimental area contributed to the control in 1963 when only 10% of the growers in the trapped area used an insecticide for hornworm control despite migration of moths into the area.

Resistance to the sweetclover weevil found. In tests conducted in cooperation with the Agricultural Experiment Station of the University of Nebraska, Melilotus infesta Guss., a species of wild sweetclover, was nearly immune to feeding by the sweetclover weevil. Only 0.4% of the leaf margin of this resistant strain was destroyed by weevil adults as compared with 57% of the leaf margin of Goldtop, a commercial yellow sweetclover. M. infesta is not satisfactory for a forage, hay, or soil-improvement crop but may provide a source from which to transfer resistance to acceptable varieties.

Ethylene oxide effective in control of diseases and pests of honey bees. New formulations of ethylene oxide with inert materials rendering this gas nonflammable and safe to use have made practical its use as a fumigant for bee keeping equipment. It acted as an effective fumigant for most of the major pathogens of the honey bee, including the causative organisms of American and European foulbrood and Nosema disease, as well as the wax moth, an insect pest of bees. The antibiotic, tylosin lactate, was also effective against American foulbrood.

Significant advance in the potential use of insect chemosterilants. Hexamethylphosphoramide (hempa) and hexamethylmelamine (hemel), dimethylamido analogs of tepa and tretamine but much lower in mammalian toxicity were effective in laboratory tests in sterilizing males of several species of insects including the house fly, mosquitoes, Mexican fruit fly, screw-worm fly, boll weevil, and codling moth. Progress in development of the chemosterilant approach to insect control has been retarded by the high mammalian toxicity of formerly available materials. This discovery of less hazardous compounds may permit earlier application of steriliation control to specific insect problems.

AREA NO. 1. VEGETABLE INSECTS

Problem. Insects and mites are important limiting factors in the production of high-quality vegetables. These pests reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase the cost of production. Use of insecticides and miticides is currently the most effective direct method of control; however, application too close to harvest may result in residue problems. There is concern over the possibility of contaminating milk and meat by feeding crop refuse or byproducts of peas, beans, sweet corn, or other vegetables treated with insecticides to livestock. Drift of certain insecticides into other fields or areas can also cause problems. Another difficulty is that a number of vegetable insects have developed resistance to certain insecticides. There is an increasing need for safe, effective, and economical methods of control that will not leave harmful residues on the marketable produce or adversely affect the flavor or quality. Research is needed on methods for better utilization of predators, parasites, and diseases of vegetable insects; development of varieties of vegetables resistant to insect attack; development and utilization of more effective traps and lures; new approaches to control including radiation, chemosterilants, and antimetabolites; and evaluation of insecticide application equipment. Availability of effective non-insecticidal methods of control would decrease the necessity for employing hazardous chemicals. Better methods are required to forecast possible insect damage before it occurs on vegetables, and to determine when it will be necessary and profitable for growers to apply control measures.

USDA AND COOPERATIVE PROGRAMS

The Department has a long-term program of applied and basic research on vegetable insects with stations at Mesa, Ariz.; Riverside, Calif.; Tifton, Ga.; Twin Falls, Idaho; West Lafayette, Ind.; Beltsville, Md.; State College, Miss.; Forest Grove, Oreg.; Charleston, S.C.; Logan, Utah; Baton Rouge, La.; and Yakima, Wash., in cooperation with the respective State experiment stations and industry. Much of the work is in cooperation with the Crops Research, Pesticides Regulation, and Agricultural Engineering Research Divisions. Work in Idaho is also cooperative with the Idaho Bean Commmission and that in Maryland with the Northern Utilization Research and Development Division and the Human Nutrition Research Division. Work in Oregon is conducted jointly with the Agricultural Engineering Research Division. Work in Louisiana is under contract to the Louisiana State Experiment Station.

The major objective of this work is to develop more effective and economical and less objectionable methods of controlling insect pests of vegetables in the field to reduce losses from these pests without leaving undesirable insecticide residues on or in the marketed product or in the soil, and

without affecting the flavor or quality of the product, or adversely affecting beneficial insects. In this research increased emphasis is being given to new approaches to insect control, and to the development of a sound biological basis for application of non-insecticidal methods. A widespread search for sex lures that can be utilized in insect detection and control is in progress. Also underway are studies of male sterilization techniques for insects such as the cabbage looper, drosophila, the banded cucumber beetle, and the Mexican bean beetle, utilizing gamma radiation and chemical sterilants. Such methods may permit control on an area basis.

The Federal scientific effort devoted to research in this area totals 24.8 professional man-years. Of this number 4.8 is devoted to basic biology, physiology, and nutrition; 4.1 to insecticidal and cultural control; 4.1 to insecticide residue determination; 2.9 to biological control; 3.0 to insect sterility, attractants, and other new approaches to control; 2.1 to evaluation of equipment for insect detection and control; 1.7 to varietal evaluation for insect resistance; 0.8 to insect vectors of diseases; and 1.3 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Research on vegetable insects at the State experiment stations is designed to provide both basic and applied information. Emphasis is being placed on developing methods for reducing the number of insecticide applications required for control. Population levels of injurious species necessary to cause economic damage are being determined. Insect predators and parasites are under investigation to determine what practices contribute to their increase. Microorganisms pathogenic to insects such as the polyhedrosis virus of the cabbage looper are being evaluated for their effectiveness. Fundamental studies on the influence of environmental factors on diapause, movement, and population size of injurious insects are being performed as methods for laboratory rearing of insects become more refined. Plant resistance and strip-planting of vegetables with other crops are promising areas under investigation. Methods of insecticide application which reduce the amount of chemical applied directly to the plant and the development of insecticides with greatly reduced residual properties are important current research areas. Studies also are being performed on the insect transmission of vegetable diseases.

The total State scientific effort devoted to vegetable insect research is 45.3 man-years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Leaf Miners. Further studies on the leaf miners that have damaged vegetables in Florida and South Carolina and chrysanthemums in Northeastern

greenhouses showed that these insects belong to the species Liriomyza munda Frick. Infestations on tomatoes were much lower in the Charleston area during the spring of 1964 than in several preceding years.

2. Sweetpotato Insects. In studies at Charleston, S.C., 3 new pests of roots of sweetpotato were discovered, including Plectris aliena, a white grub; Systena frontalis, a flea beetle; and Notoxus calcaratus, an anthicid. Considerable evidence was obtained that the tobacco wireworm damaged sweetpotato roots in Georgia.

Continued studies under contract by the Louisiana State Agricultural Experiment Station indicated that populations of banded cucumber beetle may normally be in delicate balance with predators of the pest and that the use of insecticides must be carefully controlled to avoid upsetting that balance. Fat accumulation in adult banded cucumber beetles was highest in August and higher in beetles from sweetpotato fields than in those from soybean fields. A higher percentage of mated females from sweetpotato fields contained eggs. Damage to sweetpotato roots by larvae of banded cucumber beetle and pale-striped flea beetle was similar. Adults of banded cucumber beetles were most abundant in July. Sticky traps painted bright yellow caught the most beetles. Pseudoplusia includens caused considerable defoliation of sweetpotatoes.

3. Adult Cabbage Looper Diets. In California, cabbage looper moths fed on 10% sucrose lived longer and deposited more eggs than when fed on other diets tested, including in decreasing order of effectiveness (1) 5% sucrose with 5% honey and .1% ascorbic acid, (2) distilled water, and (3) 5% yeast hydrolyzate.

4. Cabbage Looper Mating and Oviposition Studies. Also in California, 10-minute exposure to cold (50° F.), carbon dioxide, or ether, reduced mating during the following 24-hour period 4%, 58%, and 89%, respectively. Size of various types of cardboard or wire screen cages had no effect on mating with 1-5 moth pairs per cage. Mating was increased from 35% to 83% in 48-hour mating periods when the ratio of the males to females was increased from .25 to 4.

In mass rearing studies, the number of moths per container affected oviposition and longevity. Optimum moth density was determined to be 3-6 pairs for 1 pint cartons and 24-48 pairs for 6-quart oviposition chambers. Looper oviposition was increased 3-fold in the presence of UV (ultraviolet) light vs. red light and 6-fold in the presence of UV vs. yellow light.

5. Cold Effects on Cabbage Looper Eggs and Pupae. In California, the viability of looper eggs was unaffected by exposure to 50° F. for 1 or 2 weeks. Marked reduction in hatch occurred when eggs were held at 40° F. for the same periods of time.

A high percentage of adults from 4-day-old pupae exposed to 50° F. for 1 or 2 weeks were deformed. Emergence from 6-day-old pupae exposed to 50° F. for the same period of time was normal. Adults emerging from 4- or 5-day-old pupae exposed to 50° F. for 1 or 2 weeks produced few eggs and a high proportion were inviable. Adults from 6-day-old pupae exposed to 50° F. for 1 or 2 weeks produced as many eggs as moths from pupae held at room temperatures and viability was comparable.

6. Cabbage Looper Population Density and Migration Studies. Cabbage looper moth catches in light traps in cultivated vegetable growing areas at Riverside, Calif., increased gradually from approximately .05 moths per trap per night in early March to approximately 2.8 moths per trap per night in June. About equal numbers of each sex were caught. Dyed moths were recaptured at 1/4 and 1/2 mile distances from the release point. Approximately .1% of the released moths were recaptured during the period from April 23 to June 30.

7. Caterpillar Pests of Leafy Vegetables in Arizona. Continued black light studies of the flight habits and abundance of the cabbage looper, alfalfa looper, beet armyworm, yellow-striped armyworm, corn earworm, and granulate cutworm in the cultivated areas in the Salt River Valley and in adjacent desert areas indicate that desert areas are not contributing appreciable numbers of moths of any of these destructive caterpillars to the cultivated areas. Large numbers of the insects develop in the cultivated areas and fly into the desert areas during population peaks in August and September. Since the desert is dry at this time these flights are chiefly suicidal. However, they perpetuate the species in outlying and semi-isolated areas. Numbers of these insects were very low during winter months. Numbers of looper adults increased in May and again in July, reached a maximum in August and September, and decreased to a minimum in November. Corn earworm and yellow-striped armyworm moths also reached population peaks in August and September. Beet armyworm moths were far more numerous than any of the other species. All of these insects are important to agriculture in the Salt River Valley. The fall crop of lettuce is planted about the time the beet armyworm, yellow-striped armyworm, and cabbage looper adults are most abundant. Plant stands would be completely destroyed without the use of insecticides. Control of these insects is also necessary on other vegetable crops as well as on sugarbeets grown for seed and on cotton.

Release and recovery studies of reared marked cabbage looper and beet armyworm moths showed that anesthetization of moths with CO_2 and marking with lacquer on one forewing did not inhibit flight of the looper moths but may have caused slight damage to beet armyworm moths. Eighty-eight percent of marked looper moths released in large walk-in cages were recovered by traps compared to 86% of unmarked moths. Only 80% of marked

armyworm moths were recovered compared to 95% of unmarked moths. In the field, 6.9% of marked released looper moths were recovered by 8 black light traps surrounding the release point, 4.2% in 4 traps at 98 feet, and 2.7% in 4 traps at 184 feet. When the traps were moved out to 300 ft. and 440 ft. recoveries were 1.5% and 0.9% respectively.

B. Insecticidal and Cultural Control

1. Banded Cucumber Beetle. Of 61 experimental compounds compared in laboratory tests in South Carolina, 13 showed sufficient toxicity to justify further tests of their residual activity in soil.

2. Cabbage Looper. Laboratory tests in South Carolina of 54 experimental compounds disclosed 15 worthy of further testing in field plots. In field tests 8 experimental materials were effective but because of high toxicity either to warm-blooded animals or to cabbage foliage, none was satisfactory.

3. Pickleworm and Squash Vine Borer on Squash. Lindane tended to be most effective against pickleworm on summer squash in South Carolina, followed by the highest dosages of carbaryl and naled used. No difference was found between wettable powder and suspension concentrate (flowable) formulations of carbaryl.

4. Southern Potato Wireworm. In laboratory tests of 46 compounds in South Carolina, Stauffer B-10341, N-3727, and N-4446 and Shell Development 8803 were the only ones proving sufficiently toxic to larvae to warrant further testing. GS-4072 was as toxic as parathion and lindane as toxic as DDT to adults. When used at higher dosages, Bayer 38156 and 25141, Stauffer N-2790, mevinphos, and naled showed promise against larvae, and carbaryl, endosulfan, and Zectran against adults. Bayer 25141, Stauffer N-2788, a "slow-release" parathion, and Kepone (in a corn meal bait) showed promise against larvae in field tests. A "slow-release" parathion granular formulation gave 100% mortality of wireworms placed in treated soil 91 days after the application, as compared to 15% by conventional parathion granules.

5. Sweetpotato Insects. In a field test at Charleston, S.C., in which at least 6 species of insects damaged the roots, none of the insecticides tested reduced the number of injured roots by more than 32%. The currently recommended treatment, DDT at 20 pounds per acre, was generally most satisfactory.

Of 22 insecticide formulations field-tested in Louisiana for control of the banded cucumber beetle, only endosulfan gave promising results. No satisfactory method of control for this pest is available.

6. Mexican Bean Beetle. In Maryland field tests, Mexican bean beetle was controlled when granular phorate at 2 lb. per acre was placed beneath the seed. Four pounds per acre were required when the phorate was placed 2 inches to one side of the seed.

7. Dichlorvos. In Maryland, dichlorvos impregnated in polyurethane foam persisted for 7 months in killing drosophila adults. Dichlorvos was added to a polyurethane mixture at concentrations of 10% and 20% and poured into shallow receptacles. The mixture expanded into a foamy loaf-like mass that hardened in 1 to 2 hours. Flying drosophila adults not coming into contact with the surface became paralyzed within 10 minutes at the 20% strength and 2 hours at the 2% strength.

8. Beet Leafhopper on Beans. In small field plots of beans at Twin Falls, Idaho, dimethoate, mevinphos, and phorate gave promising results against the beet leafhopper, decreased the incidence of curly top, and increased the yield. In laboratory tests, each of these materials was more effective when mixed with sugar. As yet no satisfactory method of control is available.

9. Beet Leafhopper on Tomato. In a field plot experiment on tomatoes at Logandale, Nev., phorate granules at 2 pounds of phorate per acre--applied to the soil in February before planting in the seed bed--reduced the population of beet leafhoppers on weeds and tomato seedlings 50% by mid-April. Phorate granules at 2 pounds per acre applied as a topical treatment in mid-April reduced the beet leafhopper population and the incidence of curly top by 85%.

In an experiment at St. George, Utah, tomato transplants that received mevinphos emulsion in the plant hole at time of transplanting plus three topical applications of phorate granules at 2 pounds per acre had 8% curly top compared to 25% in untreated plots.

10. Corn Earworm in Sweet Corn. At Tifton, Ga., 7 new experimental insecticides gave equal or better control than the standard DDT emulsion spray. Trichlorfon also was effective. Dimethoate and dichlorvos were inferior.

At State College, Miss., good control of corn earworm was obtained with carbaryl at the rate of $1\frac{1}{2}$ pounds per acre and with Telodrin at 2 pounds per acre on sweet corn. Seven applications were made at every-other-day intervals beginning with first silk emergence.

C. Insecticide Residue Determinations

1. On Sweet Corn. At Tifton, Ga., residues of DDT were greater on silks and ear tips of sweet corn treated with DDT granules than on those treated with dusts or sprays at the same dosage of DDT. Emulsion sprays left the least residues. Variations in the quantities of DDT deposited by dust and granular treatments, however, were about twice the variation in the spray treatment.

An analytical method for Shell SD-8447 and its chlorine-containing hydrolysis product in sweet corn plants and ears was developed by pesticide chemists at Tifton, Ga., for use in field tests in 1964. The insecticide and the hydrolysis product chromatographed well in a stainless steel column

containing silicon grease on chromosorb W. Both products were completely recovered from corn plants and ears by blending with hexane-acetone and 95% was recovered with hexane alone. Hexane solutions of the concentrated extracts were cleaned in a counter current distribution apparatus.

2. On Sweetpotato. Over-tolerance residues were found by Beltsville, Md., chemists in sweetpotatoes from experimental plots in Louisiana where aldrin had been used at registered dosages. It was therefore necessary to discontinue recommendations for the use of aldrin on sweetpotato. Sweetpotatoes grown at Charleston, S.C., in soil treated with 1 lb. of Telodrin per acre prior to planting showed Telodrin residues ranging from 0.01 to 0.07 ppm at harvest.

3. On Cabbage in South Carolina. Analyses by ARS chemists in Maryland showed 0.04, 0.06, and 0.07 ppm of endrin on the usually marketed portion of cabbage sprayed with 0.4 lb./a. of endrin 33 days before harvest. Samples sprayed 41 days before harvest had 0.02, 0.02, and 0.03 ppm. On the basis of these data, USDA recommendations for the use of endrin on cabbage were discontinued.

4. On Cantaloups in Arizona. No phorate residues greater than 0.02 ppm (limit of accuracy of the analytical method) were found in mature cantaloup meats or rinds from a large-scale field plot that had been treated with 1 lb. of phorate per acre placed 1 inch under the seed at planting time.

5. On Lima Beans in Washington. Dry lima beans harvested 43 days after the last of three sprays of dimethoate at 3/4 pound per acre contained an average residue of 0.09 ppm of dimethoate. No measurable dimethoate residues were found in the dry pods or in the straw.

6. On Tomatoes in Maryland. Analysis of tomato fruits harvested at intervals after treatment with mist sprays of dichlorvos indicated that maximum residues of 8.7 ppm immediately after treatment decline to .1 ppm in 5 days and 0 ppm in 7 days.

7. On Carrots and Onions in Washington. Carrots and onions grown in soil treated the previous year with 5 lb. aldrin, 3 lb. dieldrin, or 20 lb. of DDT per acre contained significant but below-tolerance residues.

D. Biological Control

1. Sweetpotato Insects. Field and laboratory studies in South Carolina indicate that an undescribed nematode parasite of the genus Anphimermis may be an important factor in the natural control of the banded cucumber beetle in the South Atlantic Coastal areas. The general life history of the nematode was determined and a method of rearing developed. The nematode also parasitized the spotted cucumber beetle, the elongate flea beetle and the sweetpotato flea beetle.

The banded cucumber beetle was also highly susceptible in the larval stage to the nematode DD 136-bacterium complex. Studies in small soil cages in the field showed this complex remains effective longer in shaded soil than in unshaded. A greater number of infectious stage larvae of DD 136 were obtained from cadavers of cabbage loopers than from those of banded cucumber beetle larvae.

2. Cabbage Insects. In further field studies in South Carolina, weekly applications of a combination of a laboratory-cultured local strain of a nuclear polyhedrosis virus and a commercial flowable formulation of Bacillus thuringiensis were as effective against cabbage looper on cabbage in field tests during the fall of 1963 as was parathion. Similar use of the virus plus commercial flowable and wettable powder formulations of B. thuringiensis was more effective against the looper on cabbage than naled and mevinphos during the spring of 1964. When used alone, neither the virus at lower dosage nor the B. thuringiensis gave adequate protection. As used, the wettable powder was more effective than the flowable formulation.

Twenty-four insect pathogens were screened in California for effect on the corn earworm reared in the laboratory on artificial diet; 11 of them resulted in 80-100% mortality of larvae within 4 days after treatment.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sex Lure in Banded Cucumber Beetle and Spotted Cucumber Beetle. Studies in South Carolina of the sex attractant of the banded cucumber beetle indicated that traps baited with an extract of female abdomens and placed 20 feet apart in a soybean field caught at least 68% of the males in the field. Virgin females of the spotted cucumber beetle produce an olfactory male lure by the time they are 14 days old.

2. Sterilization of the Banded Cucumber Beetle. In laboratory studies in South Carolina, residues from 4% apholate spray on glass or plastic sterilized male cucumber beetles exposed to it for 15 minutes. All eggs laid by females mated to these males were infertile. Residues from 4% hemel and 4 and 8% hempa on plastic were ineffective.

3. Southern Potato Wireworm Bait. In exploratory field studies in South Carolina, a combination bait containing corn meal, soybean flour, wheat germ, and brewers yeast attracted more larvae than did soybean meal, corn meal, and tap water alone.

4. Sterilization of Cabbage Looper. In further studies in Riverside, Calif. the chemosterilants tepa, metepa, and apholate fed to cabbage looper moths induced variable degrees of sterility. Male moths that were fed tepa did not mate as frequently as untreated males. Tepa sprays, .5, 1, or 2%, induced complete sterility in male moths and metepa sprays were nearly as effective. Apholate sprays were less effective than either tepa or metepa.

Abnormal copulations in which males were unable to separate from females occurred more frequently when males were sprayed with high concentrations of tepa. In moths sprayed with tepa and dissected at various intervals, the testes showed no apparent visual differences and sperm packets were observed; ovarioles were distinctly deteriorated as compared to the ovarioles of untreated females.

Incorporation of various chemosterilants in larval feeding media resulted in high mortality. Chemosterilant treatment of pupae induced high degrees of sterility in emerged moths, but sterility was seldom complete.

5. Drosophila Attractants. Of 50 new materials tested as attractants for drosophila flies, none was superior to the Beltsville standard of 10% granulated sugar, 4% active dry yeast, 1% apple cider vinegar, and water.

6. Chemosterilant Baits Field Tested. In further studies on drosophila at Beltsville, Md., 16 chemosterilant bait stations per acre of tomatoes gave promising results in the control of drosophila in semi-isolated fields. Each bait station consisted of a gallon jar containing the standard bran-sugar-yeast-vinegar bait. The jar was sprayed inside and out with 2% of apholate. When distributed weekly for 6 weeks in replicated 1/4-acre tomato field plots at 4 per plot, 63% control of Drosophila melanogaster flies was obtained. Two-percent apholate sprayed on 4 hampers of ripe tomatoes in each plot was less effective than the apholate on the bait jars. Diazinon granules gave a maximum of 93% control at 1-pound of diazinon per acre-application, twice the dosage recommended.

Eggs from isolated females collected from apholate plots and eggs from laboratory-reared females mated to males collected from the same plots, revealed that a substantial number of each sex was sterile.

7. Mexican Bean Beetle. In Maryland, further studies on induced sterility of the Mexican bean beetle showed that females that mated with normal males in the fall were fertile in the spring whether or not they mated in the spring with sterile or fertile males.

F. Evaluation of Equipment for Insect Detection and Control

1. Insects Attacking Sweet Corn. Agricultural engineers at Tifton, Ga., have conducted experiments with new mechanical and physical methods for insect control. Preliminary work with oriented planting resulted in 61% of the corn ears growing perpendicular to the row, although there was no orientation of the foliage. Research was also continued on an electrostatic duster. Positively charged DDT and carbaryl dust gave better earworm control than negatively charged or uncharged dusts of the same insecticides. There was no significant difference in control obtained with negatively charged dusts or uncharged dusts. In another experiment a DDT emulsion spray gave better earworm control than any of the dust treatments. In the same experiment, negatively charged dust gave better control than positively charged or

uncharged dusts.

At Tifton, Ga., agricultural engineers and chemists used simulated corn ears made from filter paper to study nozzles, gallonage, and pressure. Effectiveness was measured by determining insecticide residues. Results indicate that there was an average of 19.1% more deposit on the front side than on the back side of the 2-inch tip of the ears when they were oriented 90° to the row. Ears oriented with the row received essentially the same deposit on both sides.

2. Improved Soil Sampling Methods. In sampling sweetpotato soils in South Carolina for larvae of cucumber beetles and flea beetles it was found that larvae could be removed from the soil much faster by introducing the water from below the screens rather than from above them. The washer developed for this purpose consists essentially of 3 trays with wire-screen bottoms, the screens being 8-mesh size in the top tray, 16-mesh in the middle and 32-mesh in the bottom. The trays nest inside each other and are mounted over a battery of 6 garden-hose nozzles.

3. Portable Vacuum Insect Collector. Such a collector was far superior to the standard sweep net for collecting leafhoppers on beans and related crops. Proportionally greater numbers of leafhopper nymphs were collected with the vacuum collector than with the standard sweep net at Yakima, Wash.

4. Work with Government-Owned Helicopter. In cooperation with the Agricultural Engineering Research Division at Forest Grove, Oreg., tests were initiated with the experimental helicopter equipped with spray booms that can be mounted at various positions, fore, center, and aft of the main rotor axis. Twenty-six multi-transect spray pattern tests were made--all with the boom mounted on the front ends of the skids, but with various nozzle arrangements and boom lengths and at different heights and speeds of flight. A symmetrical arrangement of 27 nozzles spaced 1 foot apart on a 26 ft. boom mounted on the front ends of the skids produced a swath of approximately 40 feet in width at the mean deposit rate, or above, when the helicopter was flown at 55-60 miles per hour at a flight elevation of 6-10 ft. Swaths of 47-56 ft. were obtained at flight elevations of 20-30 ft. at speeds of 28-32 mph. A characteristic area of lower deposit 5 to 10 feet to the right of the center line of flight was noted in all the spray patterns. A possible cause of this might be the air disturbance set up by the tail boom rotor.

5. Spray Pattern from Piper Pawnee PA-25-235 Airplane. In cooperation with the Agricultural Engineering Research Division a series of 70 spray pattern tests with this low-wing monoplane showed that an asymmetrical nozzle arrangement produced a satisfactorily uniform spray pattern over a 63 ft. swath when applied at 5-6 ft. elevations. Spray patterns of the first Pawnee tested had a zone of low spray deposit near the center. It was first thought this low deposit zone was caused by the fan-driven spray pump. However, later tests with a Pawnee equipped with a hydraulic-

driven spray pump proved the fan driven pump was not the cause but probably either the landing gear or the extended lip on the underside of the engine cowl.

G. Varietal Evaluation for Insect Resistance.

1. Sweet Corn. At West Lafayette, Ind., 28 yellow sweet corn inbreds were rated for earworm resistance. Of the 5 graded as resistant, the inbred (245 X 335) (5)1m-1m-3y-1 was the most resistant in 1963. It also had excellent resistance in 1962. From a group of 20 miscellaneous sweet corn inbreds, Tennessee inbred T24 was rated as the most resistant. The inbred has long, tight husks which probably account for its resistance. A group of 65 experimental yellow sweet corn hybrids contained 5 that rated resistant to highly resistant. The inbred parents of the 5 hybrids appear to be excellent source material for future earworm resistance studies.

Field studies at West Lafayette indicated that certain resistant sweet corn inbreds were resistant to the corn earworm due to husk characteristics. When the husks were opened and earworm larvae placed on the tip of the ears, no resistance was observed. Certain inbreds when used in single crosses seem to transmit resistance consistently even though the inbreds have not been rated as resistant. On the other hand, certain resistant inbreds seem to transmit susceptibility to their progeny. It was concluded that the best way to test the resistance or susceptibility of an inbred was to use the inbred in a number of single crosses and test the progeny. Apparently resistance or susceptibility may be masked in certain inbred lines of corn.

Corn earworms were reared in the laboratory at Tifton, Ga., on silks and kernels of sweet corn inbreds selected for their suspected influence on larval development. Nearly twice as many first instar larvae died after feeding on silks of M-119 or 380 as died when fed on P-39. Larvae survived on inbred 322 but the second year weight of the pupae was significantly lower than that of pupae taken from other inbreds.

Inbreds 166 and 259 continue to have the most transferable resistance for the earworm. Zapalote Chico, which has high resistance as an inbred due to an extremely tight silk channel, has produced susceptible crosses. Backcrossing with 81-1 and 471-U6 in hopes of producing a yellow hybrid with the earworm resistance and high quality of the white cross has shown promise. Hybrid 471-U6- X 81-1 has had a rating of high resistance in the Southern Sweet Corn Cooperative Trials but the hybrid seed is difficult to produce. The back crosses are much more vigorous and appreciably earlier than the parents. Male sterility has been incorporated into the white inbreds without significant loss of earworm resistance.

2. Sweetpotato. In field trials in South Carolina, sweetpotato breeding line L3-64 showed considerable resistance to injury by larvae of the southern potato wireworm, the white grub Plectris aliena, cucumber beetles, and at least one flea beetle. When freshly harvested roots of L3-64 and

comparable roots of Centennial, a commercial variety susceptible to injury by these insects, were offered to larvae of the wireworm, the white grub and the banded cucumber beetle in laboratory cages, each species showed a marked preference for Centennial. Banded cucumber beetle larvae reared on fresh roots of L3-64 had slower growth and lower survival than ones reared on roots of Centennial. The larvae showed little preference for cured roots of one variety over cured roots of the other. Uncured Centennial roots were much preferred to cured ones. Results of these laboratory tests indicate that a simple method of rating breeding lines of sweetpotatoes for this type of insect resistance can be developed.

In Louisiana breeding line seedling L3-64 showed a high degree of resistance to root damage by banded cucumber beetle larvae in 4 locations. Earlyport, Nugget, and L4-89 also were damaged less than Porto Rico.

3. Squash. In Washington preliminary observations of a series of clones derived from crosses of bush-type squash by T. E. Randall, Washington Experiment Station, indicate that some of these may be highly resistant to the two-spotted spider mite.

H. Insect Vectors of Diseases

1. Aphids and the Source of Lettuce Mosaic Virus. Aphids were trapped and seedling lettuce plants exposed to seven various ecological situations in the east end of the Salt River Valley of Arizona. The aphids acquired lettuce mosaic virus from weed hosts as well as cultivated plants. Virus-free seed is a partial solution to the lettuce mosaic problem, but these data show that the virus may be acquired from sources other than lettuce and transmitted to lettuce by migrant aphids.

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AREA NO. 2. POTATO INSECTS

Problem. Control of insect pests is essential to the profitable production of high-quality potatoes demanded by the consumer. There is a continuing need for research to improve present control methods as insects develop resistance to insecticides and the public demands safer, more effective, and more economical methods of insect control. The overall problem is complicated in that many of the virus diseases of potatoes are transmitted by small populations of insects that otherwise would be of little importance. Sometimes it is not known which insects are responsible. It is important to learn the identity, distribution, and ecology of the vectors of diseases of potatoes in order to make an intelligent approach to the development of methods for preventing insect transmission of the diseases. There is an especial need for research on the ecology and biological control of potato insects; and for research on the evaluation of potato varieties for insect resistance. Growing concern over problems associated with insecticides which may also include adverse effects from residues in the soil, contamination of non-target areas, and interference with the work of natural enemies of insect and mite pests, makes it imperative that an increasingly strong research effort be directed to the development of nonchemical methods of insect control or of ways of using chemicals that will avoid objectionable side-chain effects.

USDA AND COOPERATIVE PROGRAM

Basic studies on the biology, ecology, and pathology of insects that attack potatoes in the field or transmit virus diseases, as well as applied research on their control are conducted by the Department at Yakima, Wash., Orono, Me., Beltsville, Md., and Charleston, S.C., in cooperation with the respective State experiment stations, the Washington Department of Agriculture, the Washington State Potato Commission, and industry.

The Federal scientific effort devoted to research in this area totals 5.6 professional man-years. Of this number 1.4 are devoted to basic biology; 2.4 to insecticidal and cultural control; 0.7 to insecticide residue determinations; 0.3 to biological control; 0.2 to insect sterility, attractants, and other new approaches to control; 0.1 to varietal evaluation for insect resistance; 0.2 to insects that spread potato diseases; and 0.3 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The State experiment stations have an effective potato insect research program underway.

The evaluation and integration of newly-developed chemicals with currently used insecticides, cultural methods, and pathogenic agents is being carried out. Information is being obtained on the influence of pesticide treatment on the development of natural enemy populations. Analyses of both tubers and soil are being performed to determine the amount of insecticide residue present following treatment and the rate of decomposition.

Studies are in progress to establish the relationship between insect-transmitted potato diseases and their vectors. The factors influencing these basic relationships are being analyzed and promising leads obtained are evaluated for their use in control.

Varietal crosses, selected seedlings, foreign varieties, Solanum species and interspecific hybrids are being evaluated for insect resistance. Resistant and susceptible strains are being studied to determine the nature of resistance mechanisms.

A total of 8.8 man-years is devoted to potato insect research in the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Green Peach Aphids. Stem-mother green peach aphids hatching from eggs taken from peach twigs in February were colonized successfully on Malva rotundifolia in outdoor cages where the aphid reproduced in successive, agamic generations of apterous and alate individuals. The successful transfer of stem-mother green peach aphids to herbaceous plants which had never been demonstrated before confirms the practicality of removing and burning egg-infested peach prunings from orchard ground litter early in the spring as a means of controlling the green peach aphid.

2. Wireworms. Whole-wheat, bran baits placed in wireworm-infested soil in Washington yielded more wireworms in much less time than conventional screening of the infested soil during the collection of 10,000 Limonius wireworms required for insecticide screening experiments. The same number of worms were collected in 25% of the time spent in baiting as in screening.

3. Garden Symphylan. The garden symphylan injured 90% of Red LaSoda potato tubers harvested from experimental plots at Gresham, Oreg., in 1963. Russet Burbank potatoes at Harrah, Wash., were severely damaged in 1962. Symphylan damage to potato tubers is difficult, and at times impossible, to differentiate from damage caused by larvae of the tuber flea beetle.

Five pounds of dieldrin per acre disked into the soil before planting were not effective.

4. Two-Spotted Spider Mite. Eggs and nymphs of the two-spotted spider mite were found during the winter of 1963-4 in eastern Washington on overwintering sugarbeet, peppermint, wild carrot, curly dock, and red clover. Previously it had been presumed that only the adults overwintered.

A collecting board, consisting of a 9-inch square piece of coarse, cotton filter cloth was superior to a mechanical brushing machine for evaluation of two-spotted spider mite control in miticide screening experiments on potatoes and much faster than the old method. The collecting board is held beneath the infested plants and the plants struck 5 times with the hand to dislodge the mites.

5. Millipede. A millipede, Polydesmus inconstans, was responsible for damage to Red Pontiac potatoes at Dayton, Wash., and apparently had been a pest of vegetables there for several years. It is of European origin.

B. Insecticidal and Cultural Control

1. Aphids. At Presque Isle, Me., under conditions of moderate aphid infestations, only one application of a foliar spray containing the experimental insecticide UC-21149 at 1/2 lb. per acre late in July was required to hold aphid infestations below the level that would result in appreciable spread of the leaf roll virus. By contrast, two applications of UC-20047 at 2.0 lb. per acre and three applications of the commercially available insecticides endosulfan at 0.5 lb./acre, endrin at 0.25 lb., and Bidrin at 0.2 lb. were required to prevent appreciable spread of this disease. Among the newer experimental materials tested as foliar sprays, the most promising was Bayer compound 41831. Promising results were also obtained with 3 experimental systemic insecticides, American Cyanamid 47031, Chemagro 39007, and Chemagro 25141.

In Washington mixtures of schradan and Di-Syston granules gave control of the green peach aphid on potatoes superior to that obtained with schradan or Di-Syston alone. In other experiments schradan mixtures with other phosphate insecticides gave excellent control of aphids. The application of Di-Syston to the soil in bands when potatoes were planted very early in the spring, or in March or the first half of April, gave poor seasonal control of the green peach aphid whereas a later side-dressing application of Di-Syston in mid-May gave excellent control.

2. Seed-Corn Maggot in Washington. Exploratory tests showed that a diluted captan dust applied to freshly cut Russet Burbank potato seed pieces at the rate of 3/4 lb. of captan per acre protected the seed against attack by seed-corn maggot. A carbaryl dust applied to the seed at 1/3 lb. of carbaryl per acre was promising for control of the maggot but stunted the plants.

3. Wireworms in Washington. Applications of Telone, ethylene dibromide, and Vidden-D fumigants and parathion and diazinon granules made to the soil the first half of April before the potatoes were planted gave excellent control of the Pacific Coast wireworm. Di-Syston granules, applied at the same rate as the other granular formulations gave poor control of the wireworms. Exploratory field tests showed that side dressings of either phorate or parathion granules made to soil after potato seed pieces had become infested with wireworm larvae would be useful as an emergency measure for protection of the crop in non-treated fields.

Two years' study indicate that diazinon is more effective for control of wireworms on light than heavy soil. Experiments conducted in heavy-textured soil containing 6-8% of organic matter at Walla Walla in 1964 showed broadcast preplant applications of granular diazinon made at 3 lb. per acre of diazinon to be non-effective for control of the sugarbeet wireworm. However, 3 lb. phorate, 4 lb. Stauffer N-2790, and 5 lb. Bayer 37289 applied as granules gave satisfactory control. In similar heavy soil at Toppenish, Wash., 4 lb. of parathion per acre applied to the soil as a preplant spray gave excellent control of wireworms whereas 3 lb. per acre of diazinon in granular form was not effective.

4. Wireworms in South Carolina. Of 46 new materials laboratory screened against the southern potato wireworm, only Stauffer B-10341, N-3727, and N-4446, and Shell Development 8803 were sufficiently toxic for further tests. In field tests, a special slow release parathion granular formulation gave 100% mortality of wireworms put in treated soil 91 days after application as compared to 5-15% mortality by the conventional parathion granules. Kepone-cornmeal bait gave promising results.

C. Insecticide Residue Determinations

1. Aldrin-Dieldrin Residues. Further studies in Washington, Idaho, Oregon, Maryland, and South Carolina on aldrin-dieldrin residues demonstrated that under some conditions dieldrin treatments of the soil will leave as much residue in potato tubers as will aldrin treatments. Consequently, recommendations for the use of dieldrin soil treatments for potatoes were discontinued. Chemists found averages of 0.03, 0.03, and 0.097 p.p.m. of aldrin and 0.22, 0.42, and 0.69 p.p.m. of dieldrin on or in potato tubers grown in field plots in South Carolina given 2.5, 5.0, and 10.0 lb./acre, respectively, of aldrin prior to planting. Similar applications of 2.5, 5.0, and 10.0 lb./acre of dieldrin resulted in average residues of 0.17, 0.36, and 0.75 p.p.m. of dieldrin at harvest.

Emulsion-type sprays of aldrin and dieldrin at 2, 3, and 5 lb. per acre, were applied to the soil of replicated plots at Othello, Wash., Gresham, Troutdale, Prineville, and Aurora, Oreg.; and Firth, Pingree, and Idaho Falls, Idaho.; and worked into the soil before planting Russet Burbank potatoes. At harvesttime over-tolerance levels of aldrin-dieldrin

were found in potatoes from all treatments at Othello, all treatments at Troutdale except the 2-lb. aldrin treatment, and all treatments at Gresham and Troutdale but the 2- and 3-lb. aldrin treatments. Over-tolerance residues were found only in potatoes from the 5-lb. dieldrin treatment at Aurora, Oreg., and no over-tolerance was found in any treatment at Firth, Pingree, and Idaho Falls, Idaho. Evidently potatoes are more subject to residue contamination in some soils than in others. The clay and organic matter contents are thought to be important factors.

Measurable, but below tolerance, levels of aldrin were found in Russet Burbank and Red Pontiac potatoes and carrots grown the second year following broadcast applications of aldrin granules to the soil at 5 and 10 pounds per acre. Measurable, but below tolerance, levels of dieldrin were found in the potatoes and onions where 5 and 10 pounds of aldrin and 3 and 6 pounds of dieldrin had been applied. Above tolerance levels of dieldrin were found in sugarbeets and carrots in each of the 4 treatments.

2. Phosphorus Residues. Following band applications of 2-lb. rates of 3 systemic insecticides applied as granules in Washington soil at planting time, residues in potatoes at harvesttime were phorate - 0.08 p.p.m., Di-Syston - 0.09 p.p.m., and schradan - 0.27 p.p.m. No measurable parathion residues were found in potatoes treated at planting time with 3 lb. of parathion per acre. Where 3 lb. of parathion was side-dressed, one sample out of three carried a residue of 0.05 p.p.m.

D. Biological Control

1. Aphids. In Maine it was found that large populations of the lady beetle, Hippodamia 13-punctata tibialis, may not provide adequate control of aphids on the primary hosts in fall. The larval stage of these coccinellids is quite effective in controlling aphids on potatoes in summer, but the migrating populations of the adults in fall failed to be thorough in searching for aphids on the primary hosts.

The predominant species of parasite of potato aphids in Maine in 1963 was the same as in 1962, Aphidius nigripes. The next most abundant were two undescribed species of Praon. Of the parasitized aphids collected, 13% were affected by hyperparasites, the most common of which were Asaphes lucens and Lygocerus spp.

Fungus diseases, appearing in Maine in late July, were exceptionally effective in controlling the potato aphid and buckthorn aphid on potatoes. Identifications of the dead diseased aphids, made by the California Agricultural Experiment Station revealed that the predominant species of fungus was Entomophthora thaxteriana. Another species, Entomophthora coronata, was found for the first time since 1945. A third species, Entomophthora lageniformis, was found infecting aphids for the first time in 22 years of the survey study. These studies indicate that sublethal infections of fungi may reduce biotic potential of the aphids.

E. Evaluation of Equipment for Insect Detection and Control

1. The six-spotted leafhopper in Washington was attracted to green light in greater numbers than to either white fluorescent or blacklight tubes in light traps.

2. Green Peach Aphids. In Washington, deep yellow paint was superior to yellow paint diluted with white for attracting winged green peach aphids in water trap pans. A few copper sulfate crystals placed in the water pans prevented growth of algae.

3. In Washington a proprietary fertilizer attachment for a tractor sold primarily to orchardists for the deep placement of fertilizers in the soil was modified slightly and proved efficient in placing systemic insecticide granules at desired depths of 3 to 21, or more, inches prior to planting potatoes.

F. Insect Vectors of Diseases

1. Aphids in Maine. Three applications of a paraffin-base oil to young potato plants one week apart at one gallon per acre per application reduced spread of potato virus Y by 58% at Presque Isle, Me., in 1963. Most of the spread occurred after the protection provided by the oil had diminished after applications had ceased. Apparently this non-persistent virus borne externally on the mouthparts of the aphid is inactivated as the mouthparts penetrate the film of oil.

In preliminary cage tests in Maine, a foliar spray containing 1/2% chlorocholine chloride reduced spread of leaf roll by the green peach aphid 22 to 83%. The mode of action is not known. The chemical apparently penetrates the foliage as the greatest protection occurs when the plants are infested with aphids 48 to 72 hours after treatment.

2. Leafhoppers in Washington. A field bioassay of the viruliferousness of the leafhopper vectors of aster yellows in a Columbia Basin potato field revealed no inoculation of aster plants before July 3 when 15% of the plants left in the field 2 weeks became infected. Later infections ranged from 10% on July 18 and 7% on August 1.

The six-spotted leafhopper carrying a Washington strain of aster yellows caused internal discoloration in 59% of Red Pontiac potatoes produced by infected plants and 34% in Russet Burbank potatoes. In another experiment with Russet Burbank potatoes, aster yellows caused 30% discolored tubers, leaf roll 75%, and and a combination of the two viruses 71%.

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AREA NO. 3. DECIDUOUS FRUIT, TREE NUT, GRAPE AND BERRY INSECTS

Problem. Insects and mites are important limiting factors in production of high quality fruits, nuts, grapes and berries, shortening the profitable life of the trees, vines, or plants, and reducing the yield or quality of the crop. Certain insects and mites transmit diseases that adversely affect the life and productivity of the host plant. No one method of control is fully satisfactory and methods that are effective now may not be so later. At present biological, cultural and other non-chemical methods of control are only partially effective. Consequently, dependence must be placed on insecticides for control. The continued use of insecticides, however, is complicated by the occurrence of insecticide-resistant strains of an increasing number of insects and mites, by the need to avoid objectionable residues on fruits and berries and on their waste products used for livestock feed, by their detrimental effects on beneficial insects, fish and wildlife, and by contamination of non-target areas. There is a continuing need for research to develop more selective, economical and safer insecticides; and an urgent need, because of growing concern over the use of insecticides, for intensified research on alternative types of control such as those based on the use of attractants, repellents, traps, insect-resistant varieties and growth-affecting materials, including chemosterilants. More research is needed on integrated chemical-biological control programs with emphasis on less intensive spray programs, so that the maximum benefits from parasites, predators and pathogens may be realized. Research is required to determine more fully the role of insects in the transmission of important diseases affecting the production of these crops, to discover the insect and mite vectors of the diseases and to determine their host preferences, ranges, and habits. Means must then be developed to reduce or eliminate the vector populations responsible for spread of the diseases.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving entomologists, chemists, insect physiologists, and insect pathologists engaged in both basic studies and practical solution of growers' problems. Research on pome and stone fruit insects is carried on at Yakima and Wenatchee, Wash., Vincennes, Ind., Wooster, Ohio, Kearneysville, W. Va., and Fort Valley, Ga., in cooperation with the respective State Experiment Stations. Research on insects and mites affecting pecan production is carried on at Albany, Ga., and Shreveport, La.; on insects affecting the production of grape, blueberry and black walnut at Wooster, Ohio, in cooperation with the Ohio Experiment Station; and on strawberry insects at Beltsville, Md. Research on insects and mites in relation to the transmission of diseases of deciduous tree fruits is carried on at Riverside, Calif., Corvallis, Oreg., Wenatchee, Wash., and Fort Valley, Ga., in cooperation with the respective State experiment stations and the Crops Research Division.

The Federal scientific effort devoted to research in this area totals 21.5 professional man-years. Of this number 3.6 is devoted to basic biology and nutrition; 6.2 to insecticidal control; 2.9 to insecticide residue determinations; 0.6 to biological control; 3.6 to insect sterility, attractants, and other new approaches to control; 0.7 to evaluation of equipment for insect detection and control; 2.8 to insect vectors of plant virus diseases; and 1.1 to program leadership.

Additional research is in progress under grants of P.L. 480 funds (Projects E21-ENT-2 and 5) to the Institute of Pomology, Skierniewice, Poland, for studies of the differences in susceptibility and in cholinesterases in various species of spider mites as influenced by acaricides and for studies on the biological control of mites, aphids, and scale insects on deciduous tree fruits and effects of pesticides on natural enemies. Studies were also initiated by the Institute of Pomology, under P.L. 480 (Project E21-ENT-8) to study the mite fauna of Poland orchards with special reference to the relation between phytophagous and predaceous species. A portion of a grant of P.L. 480 funds (Project A17-ENT-5) to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan, for research on scale insects, fruit flies, and mites, and their natural enemies in West Pakistan is applicable to insects affecting deciduous tree fruits.

PROGRAM OF STATE EXPERIMENT STATIONS

A well rounded research program in this area is in progress in the States. Studies range from virus disease transmission by insects to the development of control measures involving comparisons of new insecticides. Integrated control measures are being developed in which the use of chemicals, cultural methods, natural enemies--in short, all factors which contribute to injurious insect control--are coordinated for maximum effectiveness. Schedules and new methods of application of pesticides are being evaluated to reduce residue levels and slow the development of pest resistance to these chemicals.

New techniques utilizing chemosterilants, repellents, and attractants are being investigated to determine their role in the maintenance of effective insect control programs. Light, bait and mechanical traps are being evaluated as control methods and as means of detecting the abundance of insects regularly during the season. Information obtained in such surveys provides a basis for insecticide treatment only when necessary.

All feasible methods of insect control are based on the life history and behavior of pest species. Consequently, a large part of the research effort is concerned with fundamental studies. The influences of environmental factors such as temperature, host relationships, light and other factors on development and mortality of several fruit insects are being investigated. In many instances, laboratory rearing of both pests and their natural enemies is being accomplished to accelerate the acquisition of biological information.

There are 49.3 professional man years dedicated to research in this area in the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Codling Moth. Large numbers of codling moth larvae and adults are needed at all seasons of the year to facilitate an uninterrupted research program. Knowledge of physical and nutritional requirements is essential to raise normal insects cheaply and in large numbers. At Vincennes, Ind., a medium was developed to rear codling moth larvae in large numbers to provide a continuous supply for use in screening insecticides, developing chemosterilants, studying diseases, and investigating chemical and sex attractants. From January 1 to June 30, 1964, more than 8,355 adults developed from larvae reared on this medium which contained apple seeds, dried apple, sugar, soybean protein, Wesson's salt, yeast, glycine, cysteine, cholesterol, alphacel, ascorbic acid, linseed oil, agar, water, potassium hydroxide, vitamin solutions, and a mold inhibitor. Ascorbic acid was essential for high yields of normal adults. At Yakima, Wash., an artificial medium composed of wheat germ, sucrose, casein, apple and agar fortified with B-vitamins, ascorbic acid, choline chloride and mineral salts was used successfully to rear codling moth larvae. Eighth-generation moths compared favorably in size with apple-reared moths and laid approximately as many viable eggs. Larvae developed at the same rate as in apples.

Biological studies showed that mature codling moth pupae floated in distilled water which permitted rapid separation of these pupae from immature pupae which sank. Differentiation of age of pupae is essential for sterilization of codling moths using either radiation or chemicals.

2. Miscellaneous Insect and Mite Pests of Deciduous Fruit. Numerous observations on biology and nutrition of deciduous fruit tree insects, other than codling moth, were made during the past year. Major emphasis was placed on the peach tree borer in Fort Valley, Ga. Only 2 field-collected peach tree borer larvae survived on variations of diets used for rearing European corn borer, corn earworm, and the pink bollworm. These larvae transformed into female moths, mated with wild males and laid eggs. Field observations at Fort Valley indicated that some of the damage attributed by growers to peach tree borer in commercial orchards was actually caused by lesser peach tree borer larvae.

In studies at Wooster, Ohio, apple maggot adults laid eggs in tiny holes punched in plastic lemons containing parts of apples or apple juice. Apple maggot larvae were reared on immature apples. Mites collected on rosetted peach trees at Fort Valley, Ga., during August and September 1963, were identified as Tetranychus schoenei.

3. Pecan and Other Nut Insects. Biological studies of nut insects at Albany, Ga., emphasized studies of factors involved in development of rearing techniques. Summer generations of hickory shuckworm moths laid an average of 50 eggs per female on nuts in cages in a screened insectary compared to only 18 eggs per female in a controlled room at 80° F. and 78% relative humidity. Fluorescent lights in the controlled room during the day and a 25-watt red lamp during the night may have prevented normal egg laying.

Efforts to rear hickory shuckworm, pecan leaf casebearer, and walnut caterpillar larvae on artificial diets were unsuccessful, possibly due to development of fungi and bacteria on the diets. Addition of sorbic acid reduced development of fungi and bacteria.

Presence of a dark spot caused by 4 glands on the dorsal side of male shuckworm larvae and newly formed pupae can be used to distinguish males from females. This differentiation is useful for biological studies of sexual behavior as well as studies of sex attractants and sterilants.

The presence of two species of plant bugs, Plaginothus repletus and Orthotylus ramus, apparently did not increase the drop of pecans. Other factors caused about 50% of nuts to shed from bloom until midsummer.

At Wooster, Ohio, eggs of the eastern walnut husk maggot, Rhagoletis suavis were laid in plastic lemons baited with unshucked black walnuts. Larvae were reared to adults on walnuts.

4. Insect Vectors of Virus Diseases. In California, no northern extension of the range of the eriophyid mite, Eriophyes insidiosus, that transmits peach mosaic, was found. No infestations have been detected in the central and northern sections of the State where the commercial production of peaches is centered. Infestations of E. insidiosus could be more easily detected on ornamental flowering peach trees in southern California than on adjacent standard varieties. This knowledge should aid in detecting the mite in new areas.

First stages of classifying the complex of related species of eriophyid mites occurring on rosaceous trees and shrubs in the Western region have been completed. The complex includes the peach mosaic virus vector originally described in this project. Other mites described in this group include a species from wild cherry, found to be a vector of cherry mottle leaf virus, a species of economic importance on pear, and 5 additional species found in associations of orchard plants.

B. Insecticidal and Cultural Control

1. Codling Moth. Development of resistance to insecticides is responsible for continual investigations of promising new insecticides for control of codling moth. In laboratory screening tests of candidate insecticides at

Yakima and Wenatchee, Wash., Bayer 42696, Bayer 50282, Geigy GS-13005 and Shell SD 9129 were the most effective materials. SD-8448 gave good control of codling moth in orchard tests. Novobiocin, an antibiotic, was 8 times as toxic as Guthion to codling moth adults. At Vincennes, Ind., approximately 65 candidate chemicals were screened as insecticides for control of codling moth, as well as control of red-banded leaf roller or two-spotted spider mite. Eleven chemicals showed promise for control of the codling moth and the leaf roller. Field studies of materials previously screened in the laboratory showed that Bayer 37344, Stauffer R-5092, American Cyanamid 47300, and Mobil MC-A-600 were effective against the codling moth but none was better than Guthion or carbaryl. Bayer 37344 was followed by severe outbreaks of woolly apple aphids at Vincennes, Ind., and Kearneysville, W. Va., when applied within 30 days of petal fall. It also reduced yield of apples.

2. Orchard Mites. Many species of mites have developed strains that are resistant to approved miticides. This situation has required an accelerated program of laboratory screening and field testing of new materials. In laboratory screening tests of candidate acaricides at Wenatchee, Wash., eight chemicals were as effective as Kelthane against both the European red mite and two-spotted spider mite, nine against the European red mite, and 17 against the two-spotted spider mite. In orchard tests at Yakima, Wash., Union Carbide 19786 and 20047 gave excellent control of the mcdaniel mite. Morestan also controlled this mite but caused spotting of 75% of the fruit. Dinocap and binapacryl were superior to Kelthane in controlling the mcdaniel mite.

Four of the 65 chemicals screened in tests at Vincennes, Ind., showed promise for control of the two-spotted spider mite. In field studies, Union Carbide 21149 was an excellent miticide, although its residue dissipated rapidly. American Cyanamid CL-47031, Morestan, and chlorbenside controlled European red mite for 50 to 60 days after petal fall when they had been applied at the pink-bud period. Two successive applications of tetradifon effectively controlled mites when used either at the pink-bud and petal-fall, or petal-fall and first-cover periods. Indopol polybutene and Foxlene formulations have consistently caused excessive phytotoxicity although they gave good mite control. Seven miticides, Union Carbide 21149, American Cyanamid E.I.-38906, chloropropylate, Kelthane, Morestan, binapacryl, and chlorobenzilate, applied to apples on July 10 and 17, gave control of European and two-spotted spider mites for 28 days following the second application at Vincennes. Morestan and chlorobenzilate were slightly phytotoxic to apples. The most promising new miticides field tested in the spring of 1964 included Union Carbide 20047A, UC 19786 and Morestan. Morestan caused phytotoxicity at Vincennes, and at Kearneysville, W. Va., in post-bloom cover sprays.

3. Plum Curculio. New insecticides that are safe to handle and can be used throughout the year are needed for control of plum curculio. Parathion and Guthion are hazardous to handle and dieldrin can be used only in the

early part of the season. At Fort Valley, Ga., five applications of Bayer 37344, Bidrin, or Imidan gave better control of plum curculio in peaches than did parathion in an orchard experiment. Bidrin caused light to moderate defoliation following the second application. UC 22708 exhibited considerable synergistic action when used with carbaryl at a 15 to 1 ratio against the adult curculio. Under simulated field conditions, aldrin continued to be very effective during the 12th season for the control of immature stages of the plum curculio.

4. Pear Psylla. Increased emphasis has been given to control of this pest because of its resistance to summer spray treatments and its possible relation to spread of pear decline on the west coast. In laboratory screening tests, Bayer 34735, Shell SD-8436, and Shell SD-8949 were as effective as Guthion against pear psylla. Morestan and Superior oils (57, 70, and 140 viscosity) were effective in delayed dormant sprays and Perthane in a cluster bud spray in orchard tests against pear psylla at Wenatchee. Better control was achieved when the pear trees were sprayed in the delayed dormant stage rather than the cluster bud stage. In field tests of eleven insecticides at Yakima, Wash., excellent control of pear psylla was obtained from three applications of Farbwerke Hoechst 2813 or Union Carbide 21149. Volck supreme oil alone or with Guthion, and Bayer 37344, were more effective than Guthion as summer sprays against pear psylla. Imidan, Perthane, and Union Carbide 20047 gave good control but had shorter residual effectiveness.

5. Insect Vectors of Virus Diseases. Studies on insecticides for control of the vector of peach mosaic virus in an isolated district in San Bernardino County, Calif., were continued for the fourth season. Insecticides have been applied each year since 1961. Diazinon was applied, as a petal fall spray, to all peach plantings in the district for control of E. insidiosus, the vector of peach mosaic virus. New infestations of mosaic were found in 3% of the trees in 1960, 5.8% in 1961, 10.5% in 1962, 4.7% in 1963, and 0.4% in 1964. The reduction in new infections since 1962 shows that control of this species of mite is resulting in a reduction in transmission of the disease.

At Fort Valley, Ga., applications of 10% granular Bayer 25141 were effective in controlling one vector of phony peach disease, Cuerna costalis, when 30 to 50 gm. were applied around the base of young peach trees. Foliar sprays of eleven insecticides were ineffective in controlling C. costalis or Homalodisca coagulata.

6. Miscellaneous Insect Pests of Deciduous Tree Fruit. Experiments to control many insect pests must be coordinated with sporadic infestations of these pests. One such species is the periodical cicada. Brood 23 of this insect is a pest in Indiana. Treatment of wooded areas surrounding orchards, as well as the apple and peach orchards, with carbaryl sprays would be desirable to control adult periodical cicada during the pre-oviposition period. Laboratory and field investigations at Vincennes

showed that Union Carbide 21149 and Zectran were more effective than carbaryl, Bayer 37344 or Mobil MC-A-600. Trees that had severe decline from nymphs feeding on their roots showed good recovery the second and third year after either phorate or carbaryl was injected into the soil in the root zone. Cooperative tests with the Ohio Agricultural Experiment Station at Wooster showed phorate was more effective than carbaryl for killing the nymphs.

At Vincennes, good control of San Jose scale was secured with Guthion, parathion, carbaryl, and Bayer 37344, applied in cover sprays at the time crawlers are active. Oil-ethion applied during the prebloom stage was no more effective than insecticides used in the postbloom sprays. Malathion and DDT, used in the cover sprays, did not maintain satisfactory control.

In laboratory screening tests at Wenatchee, Stauffer B-9564 was as effective as parathion against both apple and green peach aphids. Three other candidate insecticides tested against apple aphids and 19 against green peach aphids were as effective as parathion. Green peach aphids, apple aphids, and woolly apple aphids were controlled by injections of dimethoate in the trunks of apple trees.

In Georgia, four oil emulsions, Orchex 780, 796, 1080, and N-790, reduced the population of white peach scale infesting young peach trees. Bidrin was ineffective in late season applications against this pest.

Extensive experiments in Indiana, to develop a more economical spray program for apple pests, showed that mite control should start in the pre-bloom period, using oil, Morestan or chlorbenside, or two applications of tetradifon. An early aphicide such as benzene hexachloride or demeton was generally needed to control rosy aphid. Guthion was the most practical insecticide for use at or within 30 days after petal fall, since it controlled codling moth, red-banded leaf roller, scale, and plum curculio, and did not russet fruit. A combination of Guthion plus carbaryl in the late cover sprays gave adequate control of insects on apples in July and August. The study showed that most growers were applying too many treatments, with 5 to 7 cover sprays generally being adequate. At least three post-bloom applications of miticides were needed to control mites.

7. Berry Insects. At Beltsville, Md., in strawberry field plots, spider mites resistant to insecticides could not be satisfactorily controlled by fall sprays and early spring sprays because the mites were protected by host leaves lying on the ground. Later spring sprays of tetradifon-Kelthane mixtures resulted in effective control on upstanding foliage. Spring applications of granular phorate, Bidrin, Di-Syston and Meta Systox-R at 4 and 8 lb./acre also were effective against spider mites on strawberries.

At Wooster, Ohio, a combination of carbaryl and malathion, applied to blueberries after bloom, practically eliminated a heavy infestation of cherry

fruit worm and blueberry tip borer.

8. Pecan and Other Nut Insects. In studies of chemicals to control the pecan leaf casebearer, four applications between May 1 and July 19 of dodine, a fungicide, gave nearly complete control of this insect. Dodine had been used for control of scab in conjunction with an insecticide spray program using a July application of malathion, parathion, carbaryl, Guthion, or EPN. A February application of parathion gave better control of dormant larval stages of the casebearer than DN-289, Guthion, zineb, or dodine. Applications of 2, 4, or 8X concentrate sprays of EPN were as effective as dilute sprays in controlling pecan weevil. Soil application of granular Di-Syston (1 lb./acre) failed to control black pecan aphid and a yellow aphid Monellia nigropuntata on small potted pecan trees.

9. Insecticide Resistance. In continued research in Poland under P.L. 480 Project E21-ENT-5 for phosphorus insecticide resistance in the two-spotted spider mite, no resistant strains have been found and attempts to develop them in the laboratory have not been successful. However, strains of the European red mite resistant to methyl parathion, trichlorfon, and malathion have been found.

C. Insecticide Residue Determinations

1. Residues in Plant Parts. The amount of residues on or in fruit or foliage following insecticide applications was determined by chemists at Beltsville, Md., Yakima, Wash., or Vincennes, Ind. Residues of 8.7 ppm of Guthion on Washington pears at harvest were reduced 95% by 14 days storage followed by washing with a detergent, before canning. Residues at harvest of 1.0 to 66.7 ppm of polyolefin were found on apples from Indiana orchards treated in May with polypropene or polybutenes for mite control. Treatment in July left residues of 47.7 to 199.3 ppm on apples at harvest. At Vincennes, apples sprayed with binapacryl 21 days and 1 day before harvest averaged 0.5 and 1.7 ppm, respectively, at harvest. MC-A-600 present on harvested apples was 3.3 ppm when the interval between treatment and harvest was one day and 1.3 ppm when the interval was 21 days.

Samples of grape juice from growers' vineyards in Ohio had no trace of DDT, methoxychlor, captan, or parathion. Soil application of phorate resulted in from 3.0 to 18.6 ppm of phorate in grape foliage but less than 0.1 ppm in the fruit.

2. Residues in Soils. Applications of insecticides to foliage, as well as to soil, result in insecticide residues in the soil. Soils from 35 randomly selected southern Indiana apple orchards contained from 21 to 2,100 ppm of DDT, mostly in the upper 2 inches of soil. Samples of soil from Indiana peach orchards treated for 4 seasons with benzene hexachloride or endrin sprays applied to the ground under the trees contained 0.3 ppm benzene hexachloride and 1.1 to 1.9 ppm endrin. Soil between the trees contained less than 0.1 ppm of insecticide.

Samples of soil in Ohio, two years after soil applications of granular dieldrin for control of apple maggot or walnut husk fly, contained 7.1 to 15.2 ppm of dieldrin. Similar samples, two years after treatment with aldrin, contained up to 0.4 ppm aldrin and from 0.12 to 0.65 ppm dieldrin.

D. Biological Control

1. Codling Moth. In West Virginia, use of DD-136 nematode to control codling moth in an isolated orchard was discontinued after 4 years, since little or no decrease in codling moth injury was obtained between this orchard and untreated orchards. At the time the experiment was discontinued, 15% of the overwintering larvae were parasitized by Ascogaster, 4% were infected by nematodes and 4% by fungus. San Jose scale had built up during the past 4 years to a heavy infestation.

2. Aphids and Scale Insects. Research in Poland under P.L. 480 Project E21-ENT-2 showed that natural enemies of the European fruit lecanium scale, Lecanium corni, was more severely affected by dormant sprays than by spring sprays. In studies on lacewing fly predators of aphids, it was found that a single larva of Chrysopa sp. will destroy 100 to 521 aphids before maturity. The female of Chrysopa required honeydew in its diet for egg laying but produced most eggs when fed both aphids and honeydew.

E. Insect Sterility, Attractants and Other New Approaches to Control

1. Codling Moth. Intensive studies were undertaken on sterilization of codling moths by radiation or chemicals as a means of control at Yakima, Wash. In laboratory studies of radiation, exposure of male codling moths to 20, 30, 40, or 50 kiloroentgens (Kr) gave 78, 85, 96 and 99.6% reduction in egg hatch when crossed with untreated females. Exposure of fully developed pupae to 15, 20, 30, or 40 Kr gave 40, 75, 86, and 96.5% reduction in egg hatch when treated male moths were crossed with untreated female moths. Female moths irradiated as adults or fully developed pupae at 20 Kr produced no viable eggs. Similar results were obtained when adult moths were irradiated with X-rays. High mortality of pupae occurred after exposure of 4-day old eggs to 5 Kr or mature larvae to 10 Kr.

In laboratory studies of chemosterilants, topical application of 30 micrograms of tepa to adult moths resulted in a 99% egg sterility with no reduction in longevity or mating. Treatment of mature larvae with 30 micrograms of tepa per insect induced high larval mortality, caused larvae to hibernate, and surviving moths in many cases were deformed. Dipping 4-day old eggs for 1 minute in 5% tepa gave 87% egg mortality. No sterilization effects were noted when pupae were dipped in 5% tepa for 1 minute. Dipping adult moths for 10 seconds in 2% tepa prevented hatch of eggs when they were mated with untreated moths.

Field-cage tests resulted in a reduction of 84% in the F_1 generation when 40 male codling moths irradiated at 40 Kr were released for every untreated

female moth, compared with a 6-fold increase in infestation from populations of untreated moths. Similar results were obtained using moths treated with tepa.

A sex lure obtained from female codling moths initially was more attractive than bait or light traps. The sex lure attracted as many moths as the bait or light traps after 5 to 10 days exposure. Only males were attracted to the sex lure, while moths of both sexes responded to the traps.

Light traps were 60% more efficient than bait traps for codling moth surveys. Sixty percent of moths caught in light traps and 50% from bait traps were males. Lights attracted younger moths than baits. Dissection of female moths collected in light or bait traps showed that 40% had mated once, 18% twice, 10% three times, and 24% four or more times. Eight percent had not mated when trapped.

2. Plum Curculio. In Georgia, dips containing 2% tepa or tretamine sterilized plum curculio adults. Larvae treated with 0.25% tepa failed to emerge as adults. Six experimental sterilants did not show sufficient effect to warrant further testing.

3. Fruit Tree Borers. Studies at Vincennes, Ind., showed that male lesser peach tree borer moths were attracted to a substance given off by virgin females. Fifty-nine percent of the females used in field tests were attractive to the males, with an average of 23 males per female trap. The attractive substance may be removed to cotton by rubbing or to alcohol by maceration. Twenty-six percent of marked male moths released $2\frac{1}{4}$ miles from an orchard containing 30 female attractant traps were recaptured.

In Georgia thirty male peach tree borer moths were captured in a trap containing a single virgin female within a short time and approximately 100 males were observed flying around the trap. Methylene chloride extracts of the tips of female abdomens were less attractive than live females but more attractive than either benzene or alcohol extracts. Extracts from crushed or uncrushed abdomens were equally attractive.

4. Nut Insects. Investigations at Albany, Georgia, showed that a 15-watt blacklight trap was effective in attracting adult hickory shuckworm (1786 between March 23 and June 10), pecan nut casebearer (350 between May 2 and June 8), and pecan leaf casebearer (7942 between May 21 and June 30). Approximately 55% of the shuckworm and leaf casebearers and 50% of the nut casebearers captured were females.

F. Evaluation of Equipment for Insect Detection and Control

1. Fruit and Nut Insect Control Equipment. Comparisons of different types of sprayers and spraying techniques at Wooster, Ohio, did not show significant differences in spray residues deposited on grape leaves or fruit. In Louisiana, aerial applications of 1 pound actual parathion, 1 lb. ethion,

or $\frac{1}{4}$ lb. demeton in 5 gallons of spray per acre or 1 $\frac{3}{4}$ lb. malathion in 6 gallons per acre gave control of the mite Eotetranychus hicoriae. An aerial application of parathion gave 99% control of fall webworm larvae.

G. Insect Vectors of Diseases

1. Miscellaneous Stone Fruit Virus Diseases. At Corvallis, Oreg., transmission of a new virus disease of cherry by the pea aphid, as well as the green peach aphid, was demonstrated. At Wenatchee, Wash., studies were initiated to determine if a leafhopper, Colladonus geminatus, a nematode, or 2 species of aphids, green apple aphid and woolly apple aphid, were vectors of apple mosaic or green crinkle virus diseases. Sufficient time has not elapsed for symptom development. Results of 77 transmission tests, initiated in Georgia in 1963, to discover the vector of peach rosette virus disease, as well as tests maintained from previous years, were negative.

2. Pear Decline. Work at Riverside, Calif., culminated in strong evidence that pear psylla will inject toxins capable of producing tree damage, that this damage is acute only when high populations of psylla are present, and that trees usually recover from the effects of the toxin when psylla populations are reduced. In contrast, trees that have the pear decline disorder do not recover but progress into either the wilt and death phase or the chronic decline phase. Results of transfers of pear psylla in vector-test experiments indicate that a causal virus has been transmitted.

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AREA NO. 4. CITRUS AND SUBTROPICAL FRUIT INSECTS

Problem. Many species of insects and mites attack citrus and subtropical fruit. They reduce the yield, lower the quality, spread plant diseases, contaminate the marketable product, and greatly increase the cost of production. There is an urgent need for research to secure more accurate biological and ecological information that will provide a sound basis for the development and implementation of improved insect control methods. Additional research is needed on biological control agents, including parasites, predators, and diseases; on the integration of biological and chemical control measures to provide safer, more effective, and more economical tools to control insects which will minimize or avoid insecticide residues and hazards to fish and wildlife. Attractants, chemosterilants and other growth-affecting materials and the sterile-male technique are among new approaches to control that need expanded investigations. Protection against introduction into the United States of tropical fruit flies or other foreign injurious insect species requires research on effective, low-cost detection methods, insect control treatments that can be used to permit movement of commodities under plant quarantine regulations, and eradication procedures for use in emergency situations to eliminate incipient insect infestations.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing program involving both basic and applied research on insects and mites infesting citrus and subtropical fruits and on treatments for control of insects and related pests in commodities regulated by plant quarantines. The program is carried on at Beltsville, Md., Honolulu and Hilo, Hawaii, Riverside, Calif., Orlando and Lake Alfred, Fla., and Brownsville and Weslaco, Tex., in cooperation with entomologists, chemists, and agronomists of the respective State Experiment Stations; also at Orlando, Fla., in cooperation with the Crops Research Division; at Hoboken, N. J., in cooperation with the Plant Quarantine Division; at Mexico City, Mexico, in cooperation with the Plant Pest Control Division and with the Defensa Agricola of the Mexican Secretaria de Agricultura Ganaderia and on the islands of Guam and Rota in cooperation with the Department of Agriculture, Territory of Guam, and with the U. S. Navy and Trust Territory of the Pacific Islands. A satellite laboratory of Honolulu located at Kahului was closed October 31, 1963.

The Federal scientific effort devoted to research in this area totals 31.5 professional man-years. Of this number, 5.8 is devoted to basic biology, physiology and nutrition; 3.6 to insecticidal control; 1.0 to insecticide residue determinations; 3.4 to biological control; 9.7 to insect sterility, attractants and other new approaches to control; 1.0 to evaluation of equipment for insect detection and control; 4.0 to insect control treatments for commodities regulated by plant quarantines; 0.6 to varietal evaluation of insect resistance; 1.1 to insect vectors of diseases; and 1.3 to program leadership.

PL 480 research grants devoted to this area include: India: (A7-ENT-26), Biology of gall midges affecting mangoes with special reference to extent of damage; Pakistan (A17-ENT-5), Studies on scale insects, fruit flies, and mites and their natural enemies in West Pakistan; Greece (E11-ENT-1), Control of the olive fly with radiation or chemical sterilization procedures; Egypt (F4-ENT-3), Induced sterility in males of Mediterranean fruit fly as a means of controlling and eradicating that pest.

PROGRAM OF STATE EXPERIMENT STATIONS

The States are engaged in both basic and applied research on citrus and other subtropical fruit insects. Attempts to establish more effective complexes of biological control agents have led to the importation of new natural enemies from other areas of the world, the most promising of which are being reared in quantity and colonized in the field. The influence of adverse factors on native and imported biological control agents is being determined by correlation of field population counts with weather cycles and treatments and by laboratory studies of temperature, humidity and other factors.

Injurious species are being studied to ascertain the type and extent of damage produced by each, methods of predicting outbreaks, mass rearing methods, seasonal population fluctuations and other biological information upon which integrated control measures may be based.

New insecticides are being evaluated to determine the most effective methods of application, dosages, compatibility with other materials, phytotoxicity, effect on beneficial insects, safety of application and residue levels on and in fruit. Particular attention is being devoted to spray oils because of the safety of their use and the fact that no evidence of resistance has appeared in any of the insect pests for which they are being used.

New techniques for sterilization of citrus and avocado fruits against fruit flies are being evaluated, so that the produce may be moved from quarantine areas into uninfested areas without containing harmful residues.

The total State scientific effort concerned with citrus and subtropical fruit insects is 18.9 man years.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Citrus Insects and Mites. At Orlando, Fla., citrus bud mites were collected for the first time. Mites were found on Valencia orange trees in three groves. Techniques are being developed for mass rearing the citrus bud mites on citrus seedlings in greenhouses.

Differences in susceptibility of 14 types of citrus seedlings to feeding by rust mites was demonstrated in the laboratory. Populations of citrus rust mites increased most rapidly on Duncan, Sour, Columbia or Navel seedlings, while pink citrus rust mites (Aculus pelekassi) increased fastest on Troyer and Columbia. The latter species defoliated Temple seedlings and caused witches-broom growth of Key lime and Sour seedlings.

Studies in the laboratory showed that the females of A. pelekassi generally outnumbered the males 3:1, and males preferred the lower side of leaves. No consistent differences in behavior of Phyllocoptruta oleivora were observed. A few females of both species were observed in which an egg had ruptured and a first instar mite could be seen within the adult.

At Riverside, Calif., migration of the citrus red mite during warm sunny days in May was studied by releasing several thousand albino mites of all stages in a mature navel orange tree and examining leaf samples at frequent intervals. Adult females dispersed more rapidly upward than in any other direction. Females were recovered 2 feet from the point of release in 6 hours, 3 feet in 2 days, 5 feet in 7 days, and 6 feet in 15 days.

California red scale fertilization studies made by isolating lemons with different ratios of males to females indicated that up to 12 females were fertilized by a single male. By placing lemons infested with female scales at varying distances in the greenhouse from a source of males, it was determined that males migrated at least 40 feet for successful matings.

In the lower Rio Grande Valley, an abrupt upsurge in brown soft scale populations occurred in late June, 3 to 4 weeks later than the similar increase in 1963. This sudden increase coincided as in the past with accelerated cotton spraying. Coincidentally, a cool, late spring delayed cotton development. The upsurge in scale was accompanied by an abrupt decrease in parasite and predator populations in groves.

2. Subtropical Fruit Flies. In tests at Mexico City substitution of torula yeast in the larval rearing medium for the Mexican fruit fly resulted in recoveries and larval weights comparable to those with brewers' yeast and at 1/3 the cost. Substitution of wheat bran and wheat middlings for part of the dehydrated carrot in the rearing formula gave promising results and induced slightly earlier pupation.

The intestinal microflora of laboratory-reared adults of the Mexican fruit fly consisted of 21 different bacteria. The bacterium occurring with the greatest frequency has been determined as belonging to the genus Staphylococcus. Study of cultures indicated that symbionts are not transmitted through the egg.

Effect of intensity of light on the Mexican fruit fly was investigated with flies which emerged and were held in darkness for 2 days, then sexed and exposed for 6 weeks to continuous darkness or continuous light at 0.2, 4.0

and 13.9 foot candles from white frosted incandescent lamps. Few eggs were laid in the absence of light and at 0.2 foot candles. Oviposition was approximately equal at 0.4 and 13.9 foot candle exposures. When flies were subjected alternately for 12 hours to complete absence of light and to red, green, yellow, blue or white light, mating began 2 hours earlier under red light than with the other colors.

Activity of Mexican fruit flies sterilized with 5% tepa and 5000 r of gamma radiation was compared with that of untreated flies by timing their movement through a series of connected compartments with 1" entrances and exits. Under uniform conditions 2.3% of the irradiated flies, 4.8% of tepa sterilized flies and 10.4% of the untreated flies reached the last compartment within the same period of time.

Adult Mexican fruit flies emerged from pupae that had been exposed to 3000 r of gamma radiation at 12 days of age. These flies laid eggs, which hatched and produced larvae but failed to develop beyond the pupa stage. Application of gamma radiation by fractionated dosages produced hatch similar to a single application.

Sterile Mexican fruit fly females attempted oviposition by insertion of ovipositors into caged grapefruit. One attempt by gamma-sterilized females compared to 20 attempts by untreated females and one by tepa-sterilized females compared to 50 by untreated females were noted.

Exposure of Mexican fruit fly eggs to gamma radiation from 10 to 1000 r has not resulted in visible mutations. Selection to eliminate the light-colored median stripe on the dorsum of the fly shows a considerable reduction in the size of the marking in the F_2 generation. A genetic marker obtained from larvae and pupae subjected to low temperatures consisted of black lines on the dorsum of the abdomen and a bar on the dorsum of the thorax.

Fluorescent dye powder impregnated on 3/16-inch squares of foam rubber in a 3" layer above pupae proved effective for marking Mexican fruit flies. As the emerging adults work through the layer of rubber to the surface, dye particles adhere to the ptilinum and remain attached when it recedes. The dye can be detected in the head under ultraviolet light or the ptilinum may be forcibly extruded. Eight colors or shades of the dye fluoresce with equal brilliance. The dyes are not toxic. Dyes can be detected in flies held in lure solution for 2 weeks and then in 70% alcohol for 2 months. No decrease in fluorescence was noted in caged flies held for over 2 months.

Liberation of only males of the Mexican fruit fly is desirable in certain sterile release studies. Laborious methods must be used at present to separate the sexes. It has been observed that males predominate early in the emergence period of any one lot of pupae. A count of flies emerging during the first day from pupae of the same age showed 1732 males and 916 females, or 65.4% males. A study for selection of a strain of early emerging males is in progress.

Longevity and dissemination of the Mexican fruit fly was studied with populations of sterile flies marked lightly with atomized colored lacquer and liberated in the State of Morelos, Mexico. Four males were captured at periods ranging from 9 months 18 days to 11 months 22 days after liberation and one male was taken 11 miles from point of release.

More than 1 million marked tepa-sterilized Mexican fruit flies were liberated at 6 locations in northeastern Mexico from Nov. 3, 1963, to Feb. 5, 1964. Two trap lines were maintained just south of the Texas border, one from Monterrey via Cerralvo to Ciudad Mier (115 miles) and the other from General Teran via China to Reynosa (107 miles). Trapping stations with 5-10 traps each were established along the lines at intervals of 10 to 20 miles. The weather with almost continuous wet northers and temperatures in the low forties and fifties was not conducive to fly activity. Only 2 liberated flies were recovered 4-5 miles from one of the release sites 14-25 days after liberation.

Longevity and dissemination of marked gamma- and tepa-sterilized Mexican fruit flies were studied in harvested grapefruit groves in the Mission district of Texas. A total of 9870 flies was liberated on Febuary 6-7 and 3.3% were recovered, most of them tepa-sterilized females. Only 3 flies, all females, were captured outside the release groves, two of them at a distance of 4 miles.

In Hawaii further developments of mass rearing techniques for tropical fruit flies have reduced the cost of production from $100 to $94 per million. The new procedure which increases larval survival about 10% involves distributing eggs on strips of toilet tissue on top of the rearing medium instead of placing the eggs directly on the medium.

In Hawaii sterile females that emerged along with sterile males at a single release site showed only a slight response to trimedlure (a male lure) until 38 days after emergence, at which time flies had dispersed throughout the 1-square-mile trapped area and there was a sharp drop in the numbers of males responding to trimedlure. During the next 2 weeks catches of sterile females outnumbered sterile males more than 2-1 and exceeded the number caught during the first 2 weeks. Previous experience with wild flies has shown that non-mated females will respond to trimedlure when the male population is extremely low. Practically all of the sterile females captured during these studies had mated. This is further evidence of the sexual aggressiveness of sterile mated females in search of a male for additional mating.

In Hawaii a strain of melon fly with a genetic marker is being segregated by progressive selection. Results of screening about 39,000 F_7 and F_8 generation flies indicate that a pure strain with an easily recognized band across the anterior surface of the abdomen may be attainable.

In Hawaii the longevity of oriental fruit flies allowed to emerge and feed for up to 2 days in boxes used for aerial drops was reduced about 50% below that of flies emerging in cages. When water alone was supplied continuously to the boxed flies for 2 days and flies then removed to cages 47% survived 3 weeks. Only one third of the flies survived after 3 weeks when they were fed sugar, honey, and water the first 2 days. Nearly 70% of the flies that emerged directly into cages stocked with adequate water as well as sugar and honey were alive after 3 weeks.

The Medfly has been reared previously in small one ft^3 cages containing 1000 flies and plastic lemons used for egging. It converted readily to the mass production methods used for the melon and oriental fruit flies where 25,000 or more flies in 8 ft^3 cages were egged with large plastic oviposition containers.

3. Southern Green Stink Bug. In order to provide stock for development of a laboratory rearing method, 10,000 bugs of all stages were collected from the field. The stock has been maintained at approximately 10,000 adults and 20,000 nymphs, and daily production of egg masses has been increased to about 135. A total of 11,589 egg masses has been obtained to date with an average of about 70 eggs per mass. Although the southern green stink bug survives on a broad range of dietary materials, including fruit fly pupae, a combination of sweet corn, broccoli sprouts, and peanuts has been used as the principal diet for production purposes.

B. Insecticidal Control

1. Citrus Insects and Mites. At Orlando, Fla., five standard acaricides applied as dips failed to prevent hatch of citrus rust mite eggs, but three materials, dioxathion, Kelthane, and carbophenothion at 20 ppm gave complete kill of nymphs hatching from the eggs. Chlorobenzilate and ethion were only partially effective as residual treatments against immature stages. Carbophenothion was not effective as a contact miticide.

In field tests using single-tree plots, ethion, ethion plus oil, and Imidan gave equal control of Texas citrus mites (Eutetranychus banksi) while zineb, NIA-9102, and Pentac permitted populations to increase and Morestan and chlorobenzilate did not affect these mites as compared with untreated plots. These chemicals gave only 3 to 6 weeks control of citrus rust mites, with ethion plus oil, Imidan, and zineb slightly more effective than the other materials. Ethion plus oil and Imidan also reduced populations of scale insects. In another test, Bidrin, Shell 7438, NIA-9203, and Dithane M-45 reduced populations of Texas citrus mites while Nabac, DuPont 328 and zineb permitted population increases 3 to 6 weeks after treatment. In this experiment zineb and Dithane M-45 were equally effective in control of citrus rust mites. NIA-9203 and Bidrin reduced populations of scale insects.

At Riverside, Calif. strains of citrus red mites resistant to demeton and ovex have been reared in the laboratory without further exposure to chemicals since 1957 and 1958, respectively. Resistance to ovex is considerably more stable than to demeton. In comparison to a susceptible strain, resistance to demeton declined from 163-fold to 10-fold in 131 generations. Ovex resistance declined from 131-fold to 78-fold in 103 generations.

C. Insecticide Residue Determinations

1. Citrus and Subtropical Fruit Insects. In the lower Rio Grande Valley, studies were conducted to determine amount and extent of insecticide drift into citrus groves downwind from cotton sprayed by airplane. Sheets of mylar plastic, 1 foot square, placed in a horizontal position showed mean deposits of methyl parathion, endrin and DDT of 192 µg at a distance of 88' downwind from the nearest row of cotton, 130 µg at 288' downwind, and 9.52 µg at 788' downwind. Amounts in ppm recovered from citrus leaves were 3.53 at 88', 2.63 at 288', and 0.91 at 788'. Rate of application per acre was 1.25 lb DDT, 0.8 lb methyl parathion, and 0.3 lb endrin. Wind speeds averaged 7.5 miles per hour. Analyses were by gas chromatograph with electron capture detector.

2. Analytical Equipment. At Hoboken, N. J., the Kitagawa gas detector tubes continued to show great promise as simple safety tools for tarpaulin fumigations to determine whether hazardous gas concentrations are present in the working areas. The methyl bromide tube was sensitive to near 1 ppm (about 1/20 the present human safety limit). The ethylene oxide tube was sensitive to near 10 ppm (1/5 the present human safety limit of 50 ppm. Its high range of 35,000 ppm has also made possible the field testing of high concentrations in the fumigation. Preliminary results with HCN and carbon dioxide tubes were promising. A new thermal conductivity unit from England showed good sensitivity for methyl bromide analysis (minimum near 1/2 oz/1000 ft^3) and corroborated previous figures using other T/C sets.

D. Biological Control

1. Citrus Insects and Mites. In Florida zineb again reduced the effectiveness of natural control of Texas citrus mites in 3 orange groves. Populations of these mites on treated trees were three times those on untreated trees. Similar results were obtained with Pentac, NIA-9102, DuPont 328, and Dithane M-45.

At Riverside, Calif., the citrus red mite virus continues to show promise as a biological control agent in field tests. Spray application of virus suspensions and introduction of 5,000 laboratory-inoculated mites per tree at 6-week intervals apparently prevented mite build-up for more than a year. Infestations increased to economic levels within a few months after treatments were suspended. In another grove treatment of heavily infested plots with 10,000 inoculated mites per tree produced an epizootic which reduced the infestation below an economic level within a month.

Basic laboratory studies of disease behavior have revealed that the disease is most active in high-density populations but is not density dependent. This finding has been supported by subsequent field observations. At least a 3-fold increase in virulence of virus suspensions was obtained by delaying the processing of the dried inoculum until it was actually sprayed in the field. Infected mites are able to transmit infection within 48 to 72 hours after having been inoculated. In studies to determine mode of transmission, mites fed through plastic membranes on virus-sucrose solutions became diseased. Transmission appeared to occur when healthy mites were fed on sucrose solutions previously fed on by infected mites. Basic studies by the Insect Pathology Pioneering Research Laboratory revealed that the virus yield in diseased mites is approximately 5% by weight.

At Lake Alfred, Fla., the introduction of the predatory mite Amblydromella rickeri continued over the past year. No evidence of an overwintering establishment of this predator was obtained. Laboratory studies with Phytoseiulus persimilis on citrus mites were not favorable enough to attempt field colonization of this mite. Studies of mite populations in sprayed and unsprayed groves during the past season failed to reveal a predator or disease that could be depended upon to give consistent control of mite populations.

Armored scale populations indicated a change in the dominant species present in Florida citrus. Since Lepidosaphes beckii and Chrysomphalus aonidum, formerly number 1 and number 2 ranking scale problems in the State yielded to biological control, the dominant species are now Lepidosaphes gloverii and Parlatoria pergandii with a recent increase in Aonidiella citrina.

Studies of the biology of Micromus posticus and M. subanticus, two aphid predators, revealed a tremendous biotic potential for the two species, but these predators were not the most common species of aphid predators observed. A parasite, Anacharis sp., attacked larvae of M. subanticus but not larvae of M. posticus.

In the lower Rio Grande Valley, seven species of parasites, 5 from Israel and 2 of the most effective California species, apparently failed to become established after valley-wide releases of large numbers.

Two species of Coccinellidae, Thalassa montezumae and Chilocorus cacti proved much more effective in controlling brown soft scale on caged citrus than the dominant native parasite Coccophagus lycimnia. Five adult coccinellids per cage reduced scale populations 58 to 65%. Ten to 40 adults of C. lycimnia reduced scale populations 0 to 30%.

In a backyard urban area some distance from spraying activity, brown soft scale on citrus caged to protect it from natural biological control factors increased from 1400 to 5100, while on an uncaged tree the population decreased from 1900 to 180 in one month. Percentage of parasitism was 1.3%

on the caged tree and 3.9% on the uncaged tree. Factors other than parasites may have been responsible for the reduction of scales on uncaged trees.

Parasites were caged for one week on terminals of citrus at each of 3 locations which had been exposed to insecticide drift from nearby cotton that had been sprayed six times by air. Only 1% of the 600 parasites on terminals at a distance of 788' downwind survived and none at distances of 88' and 288'. There was little difference in survival on terminals on windward or leeward sides of the trees. Parasitism was more than twice as high on caged terminals on the windward side of the trees than on the leeward side, which was unexpected. However, the number of scale on windward terminals was about 1.6 times as heavy as on leeward terminals, which may account for the difference in parasitism.

2. Subtropical Fruit Flies. In Hawaii parasitism was high in oriental and Mediterranean fruit fly hosts and ranged from 0 to 95%. Parasite activity was exceedingly heavy in many of the preferred hosts with Opius oophilus continuing to be the dominant and most effective parasite among the many species that have been released to combat fruit fly pests. The hosts yielding average parasitism greater than 50% were banana (95%), surinam cherry (93%), strawberry guava (72%), mountain apple (64%), coffee (62%), Euphoria didyma (61%), methyley plum (60%), and guava (55%). Opius vandenboschi, O. longicaudatus, and O. fletcheri continued to be recovered in small numbers in a few of the fruit collections. Two polyembryonic parasites, Tetrastichus giffardianus and Syntomosphyrum indicum, were recovered from wild momordica and banana, respectively.

E. Insect Sterility, Attractants and Other New Approaches to Control

1. Citrus Insects and Mites. At Orlando, Fla., dipping citrus rust mite infested plants in chemosterilants at concentrations of 1000 to 4000 ppm showed that apholate was partially effective in reducing hatch of the mite eggs. Tepa and metepa were toxic to mites at the higher concentrations. Hempa and farnesyl methyl ether had no effect on populations of these mites.

At Riverside, Calif., tepa, apholate, and hempa were applied to larval males and pre-second molt females of California red scale on lemons. All 3 sterilants were more toxic to males than to females. The LC_{50} for tepa was 0.5% for males and 2.3% for females, and for hempa 0.2% for males and 3.3% for females. Apholate was practically non-toxic. No evidence of male sterilization was detected.

2. Subtropical Fruit Flies. Studies in Florida showed that $\frac{3}{4}$" x 2" wicks in plastic Mediterranean fruit fly traps held 3.5 times as much and dispensed 70% more trimedlure as did 3/8" x 2" wicks. The larger wicks need retreatment on a 6 to 8 week schedule compared to 3 to 4 weeks for the smaller wicks. Loss of oil of angelica during periods of cold weather amounted to 74% of the loss during warm weather compared to 36% for

trimedlure and only 3% for medlure. Wicks (3/8" x 2") should be retreated at intervals of 1 week with oil of angelica, 4-6 weeks with trimedlure or 8-10 weeks with medlure during winter months in Florida. These data indicate that medlure may not be a satisfactory lure for Medflies in Florida during periods of low temperatures.

Results of tests conducted in Hawaii with various dyes to mark fruit flies indicated that Eosin Y, Brilliant Yellow, and Calco Blue (oil soluble) dyes mixed with pupae at 4g/ liter or covered by fine vermiculite dyed with 10 g/ liter gave equally good results. Emergence and longevity were unaffected. The two new colors retract into the head of the flies with the ptilinum upon emergence and can be detected by crushing the head with a small amount of acetone. The Calco Blue has effectively marked melon flies released on Rota for as long as they lived--up to 4 months after the last release.

In Hawaii methods of dispersing lure-toxicant combinations for the male annihilation method of eradication have been improved. The standard cane-fiber wafers saturated with trimedlure, cue-lure, or methyl eugenol, each in combination with 3% naled, continue to kill flies attracted to them on the ground for several weeks or months. Other materials tested including large flakes of vermiculite, corncob grits, and pressed wood pellets, were less effective than the cane-fiber wafers. Cue-lure applied to foliage lasted much longer than other lures. Its effectiveness was doubled by inclusion of monoglycerides of lard and substitution of Imidan (3%) for naled. Generally baits applied to the foliage lost their effectiveness more rapidly than baits in cane-fiber wafers.

The oriental fruit fly has apparently been eradicated from the 210 square mile island of Guam by sterile fly releases at an overall cost of less than 4¢ per acre. During September 1963 low populations of the oriental fruit fly were found only in steep narrow gulches of northern Guam that were protected from typhoon winds. Typhoon Karen and Olive, which occurred in December 1962 and May 1963, respectively, destroyed most of the tree fruit host plants of this fly. A release of 1.2 million sterile oriental fruit flies at 5 points across the north end of the island close to the mouth of the valleys was made for the purpose of studying fly movement, longevity, and the effectiveness of the sterile laboratory white-marked strain. Flies from these releases spread downwind as much as 12 miles in the same pattern as had been noted for the wild flies captured in the few weeks before the release. Most of the marked oriental fruit flies disappeared within a month, and at the end of that period no wild flies were coming to the traps. Two wild flies were captured in the middle of the island fifteen miles from the release sites and additional weekly releases were made across the north end and near the areas where the two wild flies were captured. No more wild oriental fruit flies were caught on the island from November until late March, when two additional flies were taken near the extreme south end of the island. Infested imported mangoes were the suspected source of these flies and a quarantine was established to prevent importation of oriental fruit fly host fruit. No additional wild flies were found in 118 traps operated on the island for more than 100 days.

In Hawaii complete sterilization of both sexes of the oriental fruit fly, melon fly, and the Mediterranean fruit fly was obtained by dipping pupae in a 5% solution of tepa. Higher concentrations of apholate, tretamine, and metepa were generally required for the sterilization of the Mediterranean fruit fly.

A 24-hour exposure of male Medflies to a chemosterilant coating on the underside of a masonite disk two feet in diameter, with a protected wick treated with trimedlure placed in the center as an attractant, resulted in either complete elimination or marked reduction in hatch of eggs from females with which these flies were mated.

Since 1954 the Plant Pest Control Division, in cooperation with the California Department of Agriculture and the Defensa Agricola of the Mexican Secretaria de Agricultura y Ganaderia, has conducted a program of spraying in local areas along the Mexico-California border where Mexican fruit flies have been periodically detected and presumed to have been brought into Northwestern Mexico in infested fruit from the interior of Mexico. This repeated spraying of urban properties has become annoying to the residents and opposition has been encountered. Beginning in April 1964 the Entomology Research Division cooperated in a program to determine if suppression of these introductions by periodically releasing large numbers of sterile male Mexican fruit flies could be substituted for the spray program. The flies were reared, chemically sterilized, and marked at the Mexico City laboratory and flown to northwest Mexico for the weekly releases ranging from 45,000 to approximately 200,000 flies.

F. Evaluation of Equipment for Insect Detection and Control

1. Subtropical Fruit Flies. A 12,700 ft^3 fumigation chamber with a concrete and steel floor and return ducts to the floor for recirculation was tested at Tuxpan, Veracruz. Gas distribution was based on ethylene dibromide recovered at four widely separated points in the room during fumigation of oranges in sisal mesh bags. A 40% load was treated with 9 oz/1000 ft^3 and a 55% load with 11 oz. Samples of the fumigant were taken simultaneously at the beginning of the treatment period, after 30 minutes and after 2 hours. There was little difference in the amounts of EDB recovered at four sampling points in the 55% load and no difference in the 40% load.

In Hawaii trimedlure-baited traps in non-host plants caught less than half as many Mediterranean fruit flies per trap as those in host plants in three experiments involving 0.5 million sterile flies. Traps in fruiting and non-fruiting hosts caught equal numbers. Most of the flies in the three traps nearest to the release site were caught within 24 hours after emergence. Some appeared 800 feet away within 24 hours. At 2400 feet elevation the peak catches occurred between 11 and 14 days after emergence.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Subtropical Fruit Flies. Larvae of the Mexican fruit fly in fruit fumigated with ethylene dibromide die slowly. The delayed mortality caused no problem until larvae still capable of movement were found in oranges which had been fumigated at Tuxpan, Veracruz, using the authorized schedule. Fruit had been loaded on ships immediately after treatment and stored at 42°F during the 2 to 3 day voyage to Florida Gulf Coast ports. At Mexico City studies were conducted to determine the longevity of Mexican fruit fly larvae in grapefruit fumigated at 65-70°F with 24 oz of EDB and stored at temperatures ranging from 78 to 42°F. Live larvae were found at temperatures and storage periods as follows: 78°--87 hr; 70°--69 hr; 63°--161 hr; 50°--262 hr; and at 42°--120 hr. Larvae pupated after storage for 10 hr at 70°, 50 hr at 50°, and at 48 hr at 42°. The only adults which emerged were at the 48 hr storage at 42°.

Midseason oranges were fumigated with 24 oz EDB at 68°F with a 50% load and waxed after fumigation. EDB residues determined as inorganic bromide in ppm ranged from 55.4 at 12 hr to 4.2 at 20 days. Valencia oranges were fumigated with 24 oz EDB under the same conditions as the midseason oranges and half were waxed after fumigation. Residues as inorganic bromide in ppm ranged from 44.6 at 1 day in waxed fruit and 36.2 in unwaxed, to 12.4 at 15 days in waxed and 0.4 in unwaxed. At 21 days, 2.2 ppm remained in waxed fruit.

Tolerance tests with midseason oranges from Veracruz showed that fruit from that region treated with a 24 oz EDB dosage are highly susceptible to injury; over 80% were blemished or rotted. Tolerance tests with nearly a ton of naval oranges, early oranges and tangerines from the Montemorelos region showed no injury from a 24 oz dosage of EDB and rot was no greater than in the controls.

A dose of 25 kr of gamma radiation was sufficient to prevent emergence of flies from sweet peppers, eggplant, zucchini squash, or avocados containing eggs and larvae of melon, oriental, and Mediterranean fruit flies. No pupae were obtained from tomatoes irradiated at the same dose. Load densities in these treatments were approximately 12-22 lb/ft^3. Tomatoes of variety N-5 tolerated treatments at doses up to 50 kr and cold storage at 55°F for 5 days. Zucchini squash were slightly softer after treatments up to 50 kr and cold storage at 55°F for 6 days. Black Beauty eggplant became moldy and decayed after treatment at 100 kr and storage at room temperatures (79-88°F). The internal or external characteristics of the eggplants were normal at doses up to 50 kr. The fruits were much firmer at 200 kr than at 50 kr. The calyces were browned at all doses.

2. Miscellaneous Crops. At Hoboken, N. J., honeydew melons from Chile tolerated methyl bromide fumigation of 4 lb for 2 hr at 40-49°F or 3 lb for 2 hr at 50-59°, with a small margin of safety. Bromide residues (determined by Dow Chemical Company) were less than 5 ppm--well within the present 20 ppm

tolerance. Even though the residues were low, it was shown that sufficient methyl bromide penetrates the skin and pulp of the melon to give good fumigation efficiency.

Cooperative tests with the Plant Quarantine Division and the Forest Service indicated four species of dry conifer seeds would tolerate standard methyl bromide atmospheric or vacuum fumigation schedules with 1 or 24 hr aeration, but high moisture seed (10 or 15%) appeared injured when aerated for only one hour after fumigation. Vacuum fumigation may also have injured some seed with excessive moisture (15%).

Carboxide (ethylene oxide 10%-carbon dioxide 90% mixture) was very effective in small-scale fumigations against a bagworm, Brachycyttarus subteralbatus, intercepted in California on military cargo returned from Vietnam. A schedule of 15 lb for 24 hr was suggested for emergency, provisional use. Information developed on Carboxide fumigation over the past few years also made it possible to suggest its use for a quarantinable cabbageworm infesting military household effects.

H. Insect Vectors of Diseases

At Orlando, Fla., studies on aphid transmission of tristeza virus have shown no increase of tristeza virus due to alternate host plants of aphids, pretreatment starvation of aphids, acquisition or transmission feeding time, maturity of aphids, age of source of inoculum, or age of indicator plants. Aphids commonly found on citrus were also found on Spanish needles, sow thistle, black nightshade and occasionally on other weeds in citrus groves.

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AREA NO. 5. FORAGE AND RANGE INSECTS

Problem: Numerous insect pests that attack forage and range plants in various parts of the United States lower seed production, reduce the quantity and quality of forage crops, and decrease the abundance of range plants for the grazing of livestock. Certain insects are involved in the transmission of forage-crop diseases. Among the more important insect pests are grasshoppers, lygus and other plant bugs, stink bugs, the alfalfa weevil, root borers, spittlebugs, leafhoppers, and a variety of aphids including the spotted alfalfa aphid and the pea aphid. A variety of insecticides is used to control these insects but they are often costly and may create residue hazards in meat and milk as well as adversely affect wildlife. There is great need for more efficient insecticides that can be applied on forage crops and range vegetation without leaving residues harmful to man or animals or that might harm bees and other pollinating insects. Increased attention should be given to the development of non-chemical control methods. The search for insect parasites, predators, and pathogens and ways to employ them effectively should be emphasized in research. The development of crop varieties which resist attack by insects offers economical and safe insect-control procedures. Forage crops should be evaluated for resistance to major insect pests and resistant germ plasm should be made available for use by the plant breeders in crop-improvement programs. Basic studies are also needed on the feeding habits of grasshoppers under different environments that affect the abundance of these insect pests. New approaches to control of forage and range insects, such as sterilization techniques and sex attractants, should be investigated.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research on forage and range insects. Studies on varieties of alfalfa resistant to insects are cooperative with State and Federal agronomists and plant breeders, those on plant disease transmission by insects with plant pathologists, and research on insecticide residues with chemists. Grasshopper research at Bozeman, Mont., Mesa, Ariz., and Columbia, Mo., is cooperative with the respective State Experiment Stations. White-fringed beetle research is conducted at Florala, Ala. Biological control studies on armyworms and cutworms at Baton Rouge are cooperative with the Louisiana Experiment Station. Investigations on alfalfa insects are being conducted at Mesa, and Tucson, Ariz., Lincoln, Nebr., and Beltsville, Md., in cooperation with the Experiment Stations in these States. Work on white grubs at Lincoln, Nebr., is cooperative with the Nebraska Experiment Station. Research on clover and grass insects at Forest Grove, Oreg., is conducted in cooperation with the Oregon Experiment Station. Work on grass insects, plant disease transmission by insects, and insecticide residues at Tifton, Ga., is cooperative with the Georgia Experiment Station. Research on insecticide residues at Yakima, Wash., and Vincennes, Ind., is in

cooperation with Experiment Stations in these States. Studies on varietal resistance, insect vectors of plant diseases and grass insects at University Park, Pa., is cooperative with Experiment Stations in 12 Northeastern States. Certain phases of the research on forage and range insects are contributing to regional projects W-37 (Natural Factors Responsible for Grasshopper Population Changes), NC-52 (Factors Influencing the Distribution and Abundance of Grasshoppers), W-74 (Seed Chalcids Attacking Small-Seeded Leguminous Crops), and S-55 (Alfalfa Insects).

The Federal scientific effort devoted to research in this area totals 26.7 professional man-years. Of this number 4.5 man-years are devoted to basic biology, physiology, and nutrition, 4.5 to insecticidal and cultural control, 5.1 to insecticide residue determinations, 3.9 to biological control, 0.8 to insect sterility, attractants, and other new approaches to control, 0.5 to evaluation of equipment for insect detection and control, 5.3 to varietal evaluation for insect resistance, 1.0 to insect vectors of diseases, and 1.1 to program leadership.

A P. L. 480 project, (E21-ENT-9), "Insect Vectors of Virus Diseases of Various Forage Legumes" is underway with the Research Institute of Plant Protection, Poznan, Poland.

PROGRAM OF STATE EXPERIMENT STATIONS

Studies on forage and range insects comprise an important part of the research program in the States. Populations of insects are being studied in relation to meadow composition, density, age, and crop sequence or type of range. Data on physical and biotic factors are recorded and analyzed to determine their relationships to insect abundance. Studies are being performed to determine the effects of environmental conditions on life cycles and pest insect physiology. Relationships between such factors as diapause and flight patterns to body fat content are under investigation. The mechanisms by which insects orient to their hosts are being determined by comparisons of the relative attractiveness of various odors, baits, flower and foliage colors, plant shapes and humidity gradients.

Chemical control research is being performed including the comparative effectivenes of materials different application schedules, residue analyses, and relationships to cultural controls such as crop rotation, fertilization and destruction of pest breeding sites.

Biological control research includes studies of the biology and ecology of predators, parasites, and microorganisms with a view to increasing their effectiveness in reducing the abundance of pest insects or weeds. New biological agents are being introduced as quickly as their value is demonstrated.

In forage crops, studies are underway to develop plant varieties resistant to insect attack. Crosses of resistant and susceptible plants are being made to determine mechanisms of inheritance. Resistance found is being incorporated into agronomically desirable varieties. Research is also being performed on insect transmission of plant diseases.

The States' programs include 42.8 man-years of research on forage and range crops.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Grasshoppers. During 1963 there was no economic damage in Arizona by the desert grasshopper (Trimerotropis pallidipennis pallidipennis). The spring population was 64% lower than in 1962, due largely to moisture and vegetation deficiencies, but the population in the fall and winter was the highest in the past 4 years.

Grasshopper populations in range habitats in the Peeples Valley, Ariz., area decreased in 1963 for the third successive year as a result of 3 successive unusually dry growing seasons. The populations were lowest in dry forbs habitats and highest in fairly succulent Juncus meadows. Dominant species were Psoloessa delicatula, Xanthippus corallipes corallipes, and Drepanopterna femoratum, species that were of little numerical significance a few years earlier when populations were high.

In Arizona the average square yard grasshopper population in July 1963, was 0.16 in Conservation Reserve Land and 0.36 for all habitats as compared with 0.20 and 0.28, respectively, in 1962. The highest population, 0.81 per square yard, was in weedy and grassy field margins. Dissosteira carolina replaced Melanoplus sanguinipes as the leading species in the area.

In alfalfa fields in south-central Arizona, the average grasshopper population in April 1963 was about 33% lower than in 1962. Melanoplus sanguinipes was highly dominant and the population of Trimerotropis p. pallidipennis was greatly reduced. In July 1963, the average population was 0.084 per square yard, down 66% from the summer of 1962. Encoptolophus pallidus subgracilis and T. p. pallidipennis were the leading species.

At Mesa, Ariz., grasshopper nymphs were reared in cylindrical cages 1X5, 2X8, and 3X12 inches in size at the rate of two per cage. Survival to the adult stage was high, 80 to 100%, in cages of all the sizes. Males reared in the smallest-size cages had slightly deformed wing tips. The nymphal period was about the same in each size of cage. There were no consistent relationships between body measurements or adult weights and the size of the cages. When nymphs were reared in standard lantern chimney cages at rates of 2, 5, and 10 per cage, survival to the adult stage was 80 to 95% and averaged slightly higher in the cages with 5 and 10 nymphs than those with 2 nymphs.

Density of nymphs had little effect on rate of development or any consistent influence on adult body dimensions or weight. When newly-molted adults were confined in 1/4-cubic-foot cages at rates of 2, 8, and 32 per cage, there were no great differences in average longevity but egg production per female decreased moderately as the number of adults per cage increased. Laboratory-hatched nymphs were reared in 1/4-cubic-foot cages at rates of 2, 8, and 32 per cage, and the adults were continued in the same cages. The period of nymphal development was about the same at all densities, but survival to the adult stage was substantially lower with 32 nymphs per cage than with 2 and 8 nymphs. Average adult longevity and egg production per female were considerably greater in the cages started with 2 nymphs per cage than in those started with 8 or 32 nymphs.

Virgin females of Melanoplus sanguinipes, M. differentialis, and Trimerotropis p. pallidipennis laid eggs in insectary cages at Mesa, Ariz. A small percentage of the eggs hatched, but none of the nymphs survived to the adult stage. Virgin females of each species laid fewer eggs but lived longer than females caged with males.

On range recovery plots in Arizona the average grasshopper population on a sparse grass area for the period April-July 1963 was 3.8 and 3.0 per square yard in untreated fenced and grazed plots, respectively. By mid-July percentages of available grass eaten by one grasshopper per square yard in the fenced plot were 9.4 on blue grama, 13.3 on curly mesquite, and 16.0 on squirrel-tail. A downward trend in the stand of grass, owing primarily to droughty summer weather conditions, from a high in 1959 to a low by April 1963 was ended by good summer rains. In October the percentage of grass cover was 10.7 in the fenced plot and 12.9 in the grazed as compared with 40.3 and 34.3, respectively, in 1959.

At Bozeman, Mont., Hesperotettix viridis was found in the field only on broom snakeweed (Gutierrezia sarothrae), and was reared exclusively on this plant in the laboratory. Under laboratory conditions females deposited an average of 2.4 egg pods with an average of 7 eggs per pod. Nymphs passed through 5 instars in an average of 43 days. Adult life averaged 31 days. H. viridis appears to be limited in numbers by a highly selective food plant association, low fecundity, and restricted movement.

In an investigation of the genetics of a two-year cycle grasshopper (Melanoplus bruneri), a mixed population of M. bruneri and Camnula pellucida from the Big Horn Mountains, Wyo., was caged over a flat of sand in the laboratory. Eggs obtained from these grasshoppers (mainly M. bruneri) were subjected to two cold and two warm periods before any hatch occurred. All nymphs obtained were C. pellucida, indicating the possibility of a two-year cycle for this species at higher elevations.

Progeny obtained from male and female Melanoplus bivittatus exhibiting severely twisted appendages have been carried through the F_4 generation with no sign of deformity. Other cultures representing an F_2 and F_3 generation from the adults exhibiting severely twisted appendages and an F_2 and F_3

generation from normal adults are being maintained and no abnormalities have occurred. Therefore, deformities are apparently due to physical rather than genetic factors.

In grasshopper nutritional studies at Bozeman, Mont., Sephadex G-25, which separates small molecules and Sephadex G-50 which concentrates molecules of higher molecular weight were used to fractionate aqueous lettuce extracts. Previously, it was determined that the low molecular weight fraction, prepared by dialysis, contained the growth-promoting substances. However, the low molecular weight fraction prepared by the use of Sephadex G-25 proved to be toxic to nymphs of Melanoplus bivittatus. One possible explanation is that certain growth inhibitors were concentrated in the fraction at the expense of the growth factor. The low molecular weight fraction prepared by dialysis may have contained enough of the growth factor to offset any inhibition. Results of tests with Sephadex G-50 tend to bear out the above explanation. When this fraction was fed, the results were comparable to the controls, which were fed an unfractionated lettuce extract.

In order to obtain a more suitable medium for rearing grasshoppers, tests were made using 4.9%, 9.85%, 19.7%, 39.4%, and 59.1% casein. The casein in the original diet (19.7%) was optimum under conditions of this experiment. Excessive amounts of casein caused heavy nymphal mortality while less than 19.7% prevented the insects from reaching maturity.

2. Alfalfa Insects. At Beltsville, Md., alfalfa weevil larvae reared exclusively on the diet for Heliothis spp. plus an alfalfa leaf extract produced adults normal in size and capable of reproduction. The time required for larval development was about twice as long as that for larvae grown on fresh alfalfa. Physical factors of the diet are considered responsible for the slower rate of development.

Tests with a feeding arrestant isolated from alfalfa leaves with adult weevils determined the concentration for optimum response, and that high concentrations are repellent.

Non-diapausing colonies of weevils were maintained in the laboratory through a second year by continuing to rear larvae under short-day (8 or 10 hours of light) conditions. Five generations were reared as opposed to the normal one generation in the field. The effect of photoperiod on diapause was further substantiated by the fact that non-diapausing adults were obtained from larvae developing in the field in late fall.

Backcrosses of "hybrid" progeny to Eastern and Western populations of the alfalfa weevil under controlled laboratory conditions demonstrated that the two populations differ genetically and are partially isolated reproductively. Hybrids are produced only one way (E♂xW♀), are predominantly female (5.6 to 1), and perform in backcrosses, in terms of egg fertility and progeny sex ratio, as do Western weevils. A sex-linked lethal factor is

indicated. Analysis of larval blood for protein fractions showed differences between Eastern and Western populations in both number and quantity of fractions present.

Newly hatched weevil larvae were geonegative and photopositive in laboratory tests. Poor survival was obtained when newly hatched larvae were deprived of access to leaf folds and crevices indicating the importance of morphological plant characteristics.

Overwintering eggs of the alfalfa weevil in 2 fields near Beltsville decreased in viability from approximately 90% in November and December to less than 20% in January and February, indicating that spring laid eggs are the primary source of damaging larval populations.

At Tifton, Ga., first instar larvae of the alfalfa weevil were collected, using Berlese funnels, from samples of alfalfa cut at soil level on January 7, 14, 21, and 30, 1964. Sweep-net collections on the same dates yielded no larvae or adults. One adult was collected on February 20 with a sweep net and 2 on March 15. All instars were present on March 16, and two collections had 57 and 22 larvae per fifty sweeps. No eggs were found in 75 old stems dissected on February 13, or in 33 new stems dissected March 17.

Collections of adults of the Egyptian alfalfa weevil (Hypera brunneipennis) were made from fields near Tucson, Ariz., during the emergence period of 1964, to determine if sexual development could be stimulated prior to aestivation. Periodic dissections of weevils held under several different sets of conditions gave negative results in all cases, indicating this weevil, like H. postica, receives the aestivation stimulus in the larval stage.

In the fall of 1963 sexuales of the spotted alfalfa aphid were found in 20 additional Nebraska Counties. These forms now occur generally over this State except for the extreme western and the extreme eastern parts. New county records were recorded from Kansas, South Dakota, and Colorado. It appears that the sexuales reported in Wisconsin last fall are not the result of spread from the Nebraska area. In general, populations of the spotted alfalfa aphid in Nebraska remained low and there were no reports of serious economic damage.

At Lincoln, Nebr., mating of the potato leafhopper was observed 24-28 hours after transformation to the adult stage. No courtship behavior was evident, as has been reported with other species of leafhoppers. No evidence of a sex attractant was apparent.

In studies at University Park, Pa., potato leafhopper nymphs were kept alive for 2 to 6 days and adults for 17 days when fed a liquid amino acid and vitamin diet through a parafin membrane. The diet was developed by Canadian scientists to rear pea aphids.

A technique was developed for obtaining egg clusters as a source of meadow spittlebug nymphs for plant resistance studies at University Park. Adult spittlebugs were swept from alfalfa and oat stubble fields in the late summer and fall and were caged on potted alfalfa in an unheated greenhouse, and induced to oviposit on packets of paper. Egg clusters were stored at 57° F. and incubated to obtain the nymphs.

3. Clover Insects. Sweetclover weevil feeding rates at different temperatures, seasons, and light conditions were compared in the laboratory at Lincoln, Nebr. Feeding rates were highest during the fall and lowest during the midsummer. Most feeding occurred at 75° F. during the spring and summer and at 90° in the fall. Weevils collected in the summer fed significantly more in the dark than in the light, while the reverse was true for weevils held overwinter in cold storage.

4. Grass Insects. During the fall of 1963, moths of Crambus vulgivagellus occurred in great abundance in some localities of grass-producing areas of central Oregon east of the Cascades. In the more humid section west of the Cascades the predominate species was C. leachellis which was very abundant in July and August. This species was particularly numerous in some old soil bank fields of Merion bluegrass.

In 1964 collections from two blacklight traps in the Willamette Valley of Oregon showed that C. bonifatellus began emerging about April 20, but cool weather held emergence at a low level until late May when large numbers, mostly males were captured. Up to June 8, C. bonifatellus was still quite abundant in various bluegrass plantings. This species evidently has two generations annually because in 1963 a brood of moths was noted about July 10 and persisted in appreciable numbers throughout July and August. During the first week of June the light traps signaled the beginning of moth emergence of C. topiarus from lawns in the Forest Grove area. In 1963 moths of this species were abundant in the Willamette Valley throughout June and July.

At University Park, Pa., frit flies damaged reed canarygrass from June to September. Larvae fed in stems below the terminal bud, causing the blade to die, and arresting plant growth.

Populations of the white grub, Phyllophaga anxia in subirrigated hay meadows in Cherry County, Nebr., were higher in the spring of 1964 than in 1963. In 1963, no damage was observed, and grubs were rather scarce. Several small infestations found in the spring of 1964 averaged as high as 6 grubs per square foot. About 70% of the grubs were in the 2nd and 30% in the 3rd instar. When compared with records obtained in 1962 and 1963, it is most probably that P. anxia has a 3-year life cycle.

The bermudagrass mite (Aceria cynodonis) reported in 1962 in Tifton, Ga., was not found during the summer of 1963 in Arizona common bermudagrass plots where it was discovered the previous fall.

5. White-fringed Beetles. Soil chambers at Florala, Ala., were installed in a half-shade slathouse in 1956 to study the development of white-fringed beetle larvae when confined to camellia and azalea plants. These chambers were infested each year from 1956 through 1962 with newly hatched Graphognathus leucoloma fecundus larvae or eggs. No adults emerged in these chambers in any year from 1957 through 1963. Similar chambers provided with the same type of plants were installed in the open field in 1961 and infested in 1961 and 1962 with egg masses. No adults emerged in 1962 or 1963 from the chambers containing azalea plants, but adults did emerge in 1963 from the chambers containing camellia plants.

From 1955-1963, studies were conducted on the survival and rate of growth of G. leucoloma fecundus and G. peregrinus larvae in soil chambers located in a half-shade slathouse and in the open field. All chambers were provided with the same food plants--rice, ryegrass, and potatoes--to furnish living plant roots throughout the year. A portion of the chambers was examined in February, April, and June, and some were left undisturbed to determine the adult emergence. At each examination the larvae were larger in the chambers located in the open field than in those in the slathouse. In the April and June examinations the survival of G. leucoloma fecundus was greater than that of G. peregrinus. The adult emergence for both species was much less in the slathouse than in the field.

B. Insecticidal and Cultural Control

1. Grasshoppers. Experiments in Warner Valley, Calif., showed that satisfactory control of grasshoppers could be obtained by aircraft application of dieldrin at 1/2-ounce per acre in a total spray volume as low as 1 pint to the acre providing uniform coverage was obtained. This, however, was not true when the vegetative cover was dense. Spray distribution by the TBM aircraft was erratic and there were large variations in dieldrin recovery on ground samplers. Spray distribution from the Stearman was satisfactory but its flight run was only 1/2-mile compared to 2 miles for the TBM. The size of the droplets produced by both aircraft varied greatly and the mass median diameters indicated that better atomization was desirable. Good control was obtained with 12 ounces actual malathion applied by Stearman aircraft at a spray volume of either 1 quart or 1 gallon per acre and there was no difference in effectiveness between a panasol and a water formulation. Good distribution of the spray was obtained and the large majority of droplets ranged from 10- to 100-microns.

At Twin Falls, Idaho, undiluted technical malathion applied at the rate of 12 ounces per acre gave good results in 2 out of 3 trials. The poor kill could be attributed to calibration of the aircraft. Nine and 12 ounces of malathion gave good results at spray volumes of 1 pint and 1 quart per acre except where excessive wind and calibration affected the results. Six ounces of malathion gave erratic results and was generally unsatisfactory.

Bidrin at 1, 2, and 3 oz/acre and at volumes of 1 pint and 1 quart gave erratic results with plot mortalities ranging from 7 to 100%. In general the low kills occurred at the highest air temperatures (70° to 80° F). This suggests that the physical characteristics of the spray solution may have been such as to result in too fine atomization and excessive loss by evaporation and buoyancy. Excellent control was obtained in the check plots treated with dieldrin.

In Montana kills from Gen. Chemical GC-3707 in a water emulsion ranged from 85.4 to 98.5% at the dosage of 2 oz/acre and from 90.7 to 98.5% at the 4 ounce dosage. As a concentrate without dilution kills were 94.4 to 99.3% at 2 oz/acre and 98.1 to 99.5% at 4 oz/acre. Three ounces of Gen. Chemical GC-3707 per acre applied as a concentrate appeared adequate for grasshopper control. In tests with dimethoate the addition of 8 ounces of plyac and 10 gallons of blackstrap molasses per 100 gallons of spray was of questionable value. Kills from 2 ounces dimethoate-oil concentrate averaged 97.1%, from 3 ounces 97.9%, and from the aldrin check 97.6%.

In other tests in Montana 6 and 8 ounces of undiluted technical malathion per acre (7 and 9.6 ounces actual malathion) gave excellent control of grasshoppers when applied to short-grass prairie. In a swath-width experiment average kills were 98.3% at 75', 98.3% at 150', 97.5% at 225', and 92.6% at 300'. It was concluded that swath widths could be safely increased but adequate results are dependent on utilizing drift from wind to obtain coverage. The best results were obtained at wind velocities between 3 and 10 miles per hour.

2. Alfalfa Insects. Fall applications of 13 commercial and experimental insecticides for alfalfa weevil control failed to give adequate protection to first crop alfalfa the following spring at Crownsville, Md. Heptachlor at 1 lb. per acre, which in previous years gave excellent control, gave only 21% control, indicating the high level of resistance that has developed. Shell SD-7438 at 4 lb., Imidan at 4 lb., dimethoate at 1 lb. (+ 2% Igepal), and American Cyanamid CL-47470 at 2 lb. per acre applied November 12 gave approximately 80% control the following May 14. Two applications of EPN at 2 lb. per acre in October and November gave similar results.

Several insecticides applied to alfalfa in the spring of 1964 gave control 20 days after treatment that was equal to or better than the standard methoxychlor. These and their rates of application in ounces per acre were: Guthion - 8, Ethyl Guthion - 8, Methyl Guthion - 8, malathion - 16, Imidan - 8, 16, and 24, Bidrin - 16, American Cyanamid EI-43913 - 16 and EI-47772 - 6 and 12, Bayer 50282 - 12, 25141 - 16 and 24 and 41831 - 16, Geigy GS-13005 - 4 and 12 and GS-12968 - 12, Mobil MC-A-600 - 24 and Shell SD-7438 - 16 and SD-9129 - 12. Bayer 25141 at 24 ounces and Geigy GS-13005 at 12 ounces were outstanding with 95% control.

Laboratory screening of candidate insecticides against adult weevils continued with 40 new materials tested during the winter of 1963-64. Those showing most promise were: American Cyanamid EI-43913, EI-47826 and EI-52160, Bayer 50282, Hooker HRS-1631, and Shell SD-9129.

3. Clover Insects. At Forest Grove, Oreg., heptachlor granules were applied to red clover at 12 ounces per acre at monthly intervals from November 12, 1963, to March 16, 1964. Samples taken in June indicated that control of the lesser clover leaf weevil increased from 76 to 96% from November to March. The improved control in the spring was probably because this weevil is inactive throughout the winter and oviposits only in the spring. Control of the clover root curculio declined progressively from 99 to 76% with each month's delay in treatment, probably because of this pest's habit of laying eggs during mild periods throughout the winter.

4. Grass Insects. Insecticides were applied to control the complex of insects on Coastal bermudagrass and also to determine if such control increased the yield of grass. Imidan, Guthion, trichlorfon, and Bidrin applied at 2 lb. per acre controlled the phytophagous insects with resultant increase in yield. The same insecticides applied at 1 lb. per acre at a later time controlled the fall armyworm and the leafhopper complex.

In a second test carbaryl and Union Carbide UC-8305 were applied to Coastal bermudagrass at 1 lb per acre. Carbaryl gave highest control of the fall armyworm and cicadellids and a 32% increase in yield. Union Carbide UC-8305 gave poorer control and increased yields only 12% over untreated plots.

Phorate, dimethoate, and Di-Syston at 2 lb. per acre were tested at Tifton, Ga., to control the spittlebug, Prosapia bicincta, on Coastal bermudagrass. Phorate controlled the adults and gave 100% control of nymphs two weeks after application. Phorate increased yields 40% over the check. Dimethoate and Di-Syston failed to control the spittlebug at the dosage tested.

Granular formulation of carbaryl, carbophenothion, and endosulfan were applied at 1 lb. of the toxicant per acre followed by a second application 17 days later. Only endosulfan controlled the spittlebug nymphs. Control was still evident 3 months after the second application. There was no significant increase in yield due to treatment.

Granular formulations of lindane and endosulfan were applied to Coastal bermudagrass at 1/4, 1/2, 1, and 2 lb. and phorate at 1/2 and 1 lb. per acre to control adult spittlebugs. Lindane at all 4 rates and phorate, at 1/2 and 1 lb. gave good control. Treated plots remained green all summer with no evidence of browning while untreated areas were brown and dying.

Sprays of endrin at 0.125 lb. per acre, lindane at 0.25 lb., and methoxychlor at 1 lb. were applied to Coastal bermudagrass. All 3 insecticides gave 95% control in October and low nymphal populations the following spring.

5. White-fringed Beetles. At Florala, Ala., in 1963, 25 materials were tested as soil insecticides against newly hatched white-fringed beetle larvae. All materials were used at rates of 1, 5, and 10 lb. in 403.3

cubic yards of soil (the upper 3 inches of an acre). DDT at rates of 1, 5, and 10 lb., and dieldrin at rates of 0.5, 1, and 2 lb. were used as the standards. The pots were infested on August 20-21, and examined October 29-November 20. Telodrin and Shell SD-5532 gave complete mortality at all dosages. General Chemical GC-6593 gave 99.7% control at the 5- and 10-lb. dosages. Shell Compound 4072 gave complete mortality at the 10-lb dosage. Monsanto CP-42320, CP-42366, CP-42527, CP-43856, CP-43858, and CP-44016 gave 34 to 55% control at the 10-lb. dosage. The other materials gave little or no control at any dosage. Dieldrin at a 0.5-lb. and DDT at 5-lb. dosages gave complete mortality.

In 1963 Graphognathus peregrinus adults were collected from an area near Semmes, Ala., which had received dieldrin surface treatments at intervals since 1954, and also from an area which had received no insecticidal treatments. Larvae reared from these two lots of adults were placed in soil treated with dieldrin at the following rates: 0.01, 0.03, 0.05, 0.07, 0.1, 0.2, and 0.5 lb. in 403.3 cubic yards. The larvae were installed on September 23 and the soil was examined on December 2-5. None of these dosages gave any control of the larvae from the treated area. Dosages of 0.2, and 0.5 lb. gave complete mortality of the larvae from the untreated area, and the 0.1-lb. dosage gave 99% control. Dosages of 0.2 and 0.5 lb. gave complete mortality of G. leucoloma fecundus larvae from the Florala area, and the 0.1-lb. dosage gave 98% control. In 1963 tests at Florala, Ala., showed that 0.07 lb. of aldrin and 0.03 lb. of heptachlor per 403.3 cubic yards of soil gave complete mortality of newly hatched white-fringed beetle larvae.

C. Insecticide Residue Determinations

1. Dimethoate Residues. At Tifton, Ga., silage corn was treated with dimethoate, at 16 and 32 ounces per acre on July 23, and the corn ensiled the following day. Immediately after application residues were 22.44 and 56.90 ppm from the 16- and 32-ounce treatments, respectively. Immediately before ensiling the residues from the 16 and 32 ounce levels were 2.65 and 14.68 ppm, and after 80 days storage 1.39 and 8.44 ppm, respectively. After 81 days the silage was fed groups of dairy animals. No significant differences were found in the dimethoate equivalents in milk and it was concluded that dimethoate in the feed at these levels produced no detectable residue in the milk.

Blood samples showed that the cholinesterase activity of each animal varied from day to day, usually in a range of ± 10%. Groups of beef animals were also fed the treated silage and blood samples taken. Although some depression of activity was observed it was not significantly different from the control group and it was concluded there was no blood cholinesterase effect in either the dairy or beef cattle from feeding corn silage containing 1.1 and 6.7 ppm dimethoate.

At Vincennes, Ind., analysis of alfalfa treated with dimethoate at rates of 0.5, 0.25, and 0.125 lb. per acre on August 17 was sampled immediately after spraying and on August 18 and 24 and September 1 and 7. The initial deposits were 39.2, 17.0, and 5.6 ppm, respectively. On August 24 they had decreased to 1.6, 0.5, and 0.2 ppm, respectively, and by September 1 the deposit even in the most heavily treated plots was less than 0.1 ppm.

At Yakima, Wash., analysis of range grass treated with dimethoate at 3 ounces per acre showed residues immediately after treatment ranged from 17.9 to 86.9 ppm from an oil formulation and 81.6 ppm with a water formulation. Twenty-one days after treatment the residues ranged from 4.9 to 27.4 ppm with the oil formulation and 4.7 ppm with the water formulation.

2. Endosulfan Residues. At Tifton, Ga., two applications of endosulfan at 1 lb. per acre were made to Coastal bermudagrass. Analyses of the grass, trash, and soil 96 days after the last application showed that 13.7% of the amount originally applied remained on the pasture. Most of the residue was on the soil. The residue on grass, trash, and soil consisted of endosulfan A and B; no decomposition products such as the metabolite, diol, or corresponding ether were detected. The results indicate that endosulfan is fairly persistent.

3. Heptachlor Residues. Analyses at Yakima, Wash., showed residues of heptachlor and heptachlor epoxide ranging from 0.06 to 0.037 ppm in red clover that had been treated with 12 ounces to 2 lb. of heptachlor per acre 69 to 236 days before harvest.

4. Imidan Residues. At Tifton, Ga., Imidan was applied to silage corn at 4 ounces per acre. The corn was sampled immediately after spraying and at intervals of 1, 2, 4, and 7 days and the corresponding residues were 3.12, 0.33, 0.22, 0.10, and 0.01 ppm, respectively.

Imidan was also applied at 4, 8, and 16 ounces per acre to Coastal bermudagrass. One day after treatment, the residues for 4, 8, and 16 ounce rates were 18.5, 42.1, and 129.0 ppm on a dry weight basis. On the fourteenth day the residues were 0.18, 0.11, and 0.17 ppm.

5. Residues of Phorate and Diazinon on Prairie Grass. Prairie grass 1 to 2 inches high was treated with granular formulations of phorate and diazinon for control of white grubs. Samples of mature grass about 24 inches high were collected and analyzed at Vincennes, Ind. Grass treated with 4 lb. of diazinon per acre contained less than 0.05 ppm of diazinon at maturity, and that treated with 3 lb. of phorate per acre contained less than 0.01 ppm of phorate.

6. Residues of General Chemical GC-3707 and Bayer 25141 on Range Grass. General Chemical GC-3707 was applied at the rate of 2 and 4 ounces per acre. Analyses at Yakima, Wash., showed that residues immediately after treatment were 15.5 and 15.8 ppm for the 2- and 4-ounce dosages applied as an

emulsifiable concentrate and 17.6 and 37.6 ppm for oil concentrate formulations. Fourteen to 28 days after application the residues ranged from 0.1 to 2.4 ppm.

Bayer 25141 was applied at the rate of 2 ounces of active ingredient per acre to range grass. Initial residues of 32.0 ppm declined to 8.9 ppm 28 days after spraying. The same plots were resprayed a month after the first application and showed residues of 32.2 on the day of spraying and 10.4 ppm 28 days later.

7. Soil Insecticide Residues. At Tifton, Ga., soil samples treated with aldrin, dieldrin, and heptachlor and bioassayed with newly hatched white-fringed beetle larvae for periods of 87 to 93 days, were analyzed by electron affinity gas chromatography. Results of the bioassays were related to the chemical data to provide initial minimal LC_{100} values for aldrin (97 ppb), dieldrin (56 ppb), and heptachlor (ca 46 ppb). About half of the heptachlor was lost during the bioassay, 1-hydroxy chlordene diminished rapidly, and gamma chlordane (impurity in technical heptachlor) was more persistent than heptachlor. Small quantities of heptachlor epoxide were detected during the latter part of the bioassay. Dieldrin was very persistent, while aldrin residues diminished markedly with the formation of appreciable quantities of dieldrin. Vertical distribution of the insecticide varied widely but the top layer of soil generally contained a lower concentration.

D. Biological Control.

1. Grasshoppers. In August 1963, at San Carlos, Ariz., 2.5% of the grasshoppers were parasitized by sarcophagids, and parasitism ranged up to 7% in local areas. On September 11 at San Rafael Valley 16.7% of mixed populations of Boopedon nubilum and Morseiella flaviventris were parasitized by nemestrinid flies in comparison with none in 1962. In late summer and fall on rangelands in southeastern Arizona, mites (Eutrombidium spp.) were commonly found on Melanoplus sanguinipes, M. lakinus, M. gladstoni, and Brachystola magna.

At Bozeman, Mont., studies on Nosema locustae as an agent for the biological control of grasshoppers showed that this protozoan infects, in varying degrees, all species of grasshoppers thus far tested. During the first year of a field study in Camas County, Idaho, more than 5,000 grasshoppers were examined for spores of which approximately 5% were infected. In addition to giving information on host range and some effects of the disease, the study showed that, during a single season, the disease can increase in geographical distribution and infection levels.

During 1963, N. locustae was introduced into 3 isolated populations to test its possible field application for the control of grasshoppers. At 2 of the sites spores were applied on moistened bran and infected grasshoppers were released at the third site. Near the areas of spore applications,

subsequent sampling indicated that approximately 30% of the grasshoppers had become infected. Infected specimens were not collected at the site where the infected specimens were released. However, because a severe epizootic caused by a fungus virtually eliminated grasshopper populations at these locations, it was not possible to determine the full effects of the applications.

During November, 1963, an undescribed species of Goniopsita (Diptera: Chloropidae) was reared from Melanoplus sanguinipes egg pods. Studies have shown that the fly larvae utilize several eggs during development and that pupation may take place either inside an egg or in the egg pod. This fly is of interest since it is the first species found in the New World with these particular habits, as well as being the first New World species of Chloropidae found in association with grasshoppers. Also of interest is the fact that the fly has not been found in association with any other grasshopper species. Another species of Goniopsita, which is associated with grasshopper eggs, has been described from Russia.

At Columbia, Mo., research on the biology of the red grasshopper mite Eutrombidium trigonum indicated that there are 3 peaks of mite infestation during the summer corresponding roughly with the appearance of adults of the prevalent grasshopper species. This mite overwinters in the nymphal and adult stages providing a wide time span for grasshopper infestation in the spring and summer. Adult females consumed an average of 7.5 grasshopper eggs while males consumed 2.7 eggs. Nymphs consumed about 2.4 eggs each. Mating is indirect through the deposition of stalked spermatophores by the males which are subsequently picked up by the females.

2. Spotted Alfalfa Aphid. Surveys made in Arizona and parts of New Mexico revealed that Trioxys utilis, one of three imported wasp parasites of the spotted alfalfa aphid was widespread in this area. The other two, Praon palitans and Aphelinus semiflavus, were not recovered during the past year, and their scarcity since 1961 indicates they will not be important in controlling the spotted alfalfa aphid in the Southwest. Attempts to recover imported lady beetles and lacewings released in Arizona in 1957 and 1958 were negative.

Biweekly observations in 1963 in 4 untreated alfalfa fields near Mesa, Ariz., showed that the spotted alfalfa aphid was scarce, attributable, at least in part, to high parasitization by Trioxys utilis. The data suggest a close relationship between abundance of lady beetles and abundance of the spotted alfalfa aphid and that the abundance of these predators in alfalfa fields is a function of abundance of the aphid. During the early part of 1964 populations of natural enemies were lower and the spotted alfalfa aphid populations higher than a year ago due partly to weather conditions which favored the aphid over parasites and predators.

3. Meadow Spittlebug. At University Park, Pa., from 1 to 7% fall collected meadow spittlebugs were infested with a dipterous parasite identified as a

tachinid, Alophorella aeneoventris. The meadow spittlebug was a new host record for this parasite.

4. Alfalfa Weevil. The alfalfa weevil continued to spread in 1964 in Vermont, New York, Ohio, and Arkansas, and was found for the first time in Illinois, Indiana, Louisiana, and Missouri. Releases of parasites were continued in New Jersey, Pennsylvania, Kentucky, New York, and Illinois. Bathyplectes curculionis has built up and spread from release sites in New Jersey and Virginia. Rearings in 1964 from releases made 1, 2, and 3 years previously showed 0.2, 6.7, and 11.2% parasitism, respectively. Tetrastichus incertus, a larval parasite, has been recovered from two release sites in Pennsylvania and has spread 50 - 55 miles from one site in 2 years. Microctonus aethiops, a solitary parasite of new adults, has been recovered and is spreading in New Jersey. B. anura was released in Pennsylvania in 1963 and recovered in 1964. Three other species have been released but not recovered.

5. Armyworms and Cutworms. At Baton Rouge, La., armyworm populations were extremely light. There were scattered light infestations of fall armyworm during the summer and moderate infestations late in the season. Parasitism was very light in a summer collection, but ranged up to 66% (all by Chelonus texanus) in late fall collections. The incidence of disease was extremely light.

Studies were conducted to determine the feasibility of securing parasitism data by dissection of preserved host larvae. Thirteen lots of Pseudaletia unipuncta totaling 481 larvae and 12 lots of Laphygma frugiperda totaling 620 larvae were collected. Parasites were recovered from part of each lot by conventional rearing and from the balance by dissection for a comparison of the results with each method. The results of dissection with Laphygma showed promise, at least in localities where Chelonus is the predominant parasite. The percentage of parasitism by dissection was 35.6 and by rearing 43.7. The results with Pseudaletia were less satisfactory. The average parasitism by dissection was only 16% whereas 33.3% was obtained from the reared material. Many of the parasites of Pseudaletia have a longer period in the host and therefore may be smaller and harder to detect. The time per larva needed for dissection was shorter with Laphygma than with Pseudaletia.

E. Insect Sterility, Attractants, and Other New Approaches to Contol

1. Grasshoppers. Thirty-six extracts from body sections of adult M. sanguinipes and 43 extracts from body sections of M. differentialis were tested as possible sex attractants at Bozeman, Mont. None of the extracts exhibited any attractiveness to adult male and female grasshoppers.

2. White-fringed Beetles. At Florala, Ala., tests to determine if white-fringed beetle adults are attracted to certain plants by odors or sight were conducted in 1963. Potted plants were covered with double wire cages to prevent the beetles from feeding on the foliage. Similar cages were used over empty pots as a check. Adults were released in the center of a 24- by

24-foot area surrounded by a barrier. Slightly more beetles were observed on the cages containing plants than on the empty check cages. The ratings were obtained by dividing the number observed on the cages containing plants by the number on the check cages. The rating for cocklebur was 1.44; cowpea, 1.53; and chrysanthemum, 1.37. Plants infested with adults were compared to plants only. Plants infested with adult beetles had the following ratings: cocklebur, 1.55; chrysanthemum, 2.72; peanut, 1.70; and cowpea, 0.87. Peanut plants which had been fed upon by adults were compared to peanut plants without adult feeding and had a rating of 1.10. Cages containing beetles without plants were compared to empty cages and had a rating of 1.40. In 1963, two areas, each 30 by 30 feet, were planted to corn with a peanut planting in the center. The areas were surrounded with a metal barrier to confine adults. Field-collected adult white-fringed beetles were released at the 4 corners of the areas, or 15.5 feet from the peanut planting. In one test where the area was kept free of all vegetation except that planted, only 14.1% of the beetles released in the area found the peanut planting. In the second test where a hill of cowpeas was planted between each hill of corn and the grass was allowed to grow, 24.9% of the beetles released in the area found the peanut planting.

F. Evaluation of Equipment for Insect Detection and Control.

1. White-fringed Beetles. Tests were begun in 1960 to study the relative effectiveness of strip and broadcast applicaltions of certain insecticides against the white-fringed beetle on non-cultivated land. The special applicator used in these tests was constructed to apply granular formulations of insecticides in narrow bands 12 inches apart on the soil surface in such a manner that the insecticide would not come in contact with the plant foliage. The insecticides were applied in October 1960, and the plots were infested with white-fringed beetle egg masses in 1960, 1961, and 1962. The larval populations were determined in April-May 1961, 1962, and 1963. Aldrin, chlordane, dieldrin, heptachlor, and carbaryl were used at two or three rates. The broadcast applications gave better control than the strip applications during the first year following treatment, but during the second and third years the two types of treatment were equally effective. Carbaryl was not effective as a surface treatment on noncultivated land. The machine used to make the strip applications disturbed the soil surface, thereby enabling the newly hatched larvae to penetrate the soil more readily. In plots which received no insecticide the soil disturbance from the machine caused a 91% increase in survival over that which occurred in untreated nondisturbed plots in 1961, and a 61% increase in 1962, but no appreciable difference in 1963. The smaller dosages of aldrin, chlordane, dieldrin, and heptachlor were less effective than the larger ones.

G. Varietal Evaluation for Insect Resistance.

1. Spotted Alfalfa Aphid. At Tucson, Ariz., screening 60 flats of Hairy Peruvian and Chilean alfalfa and 23 breeder-selected lines for resistance to biotype ENT A of the spotted alfalfa aphid yielded 60 promising plants.

Stem-cage tests indicated that 39 of these were sufficiently resistant to be appraised for agronomic qualities.

Progress in developing resistance to the spotted alfalfa aphid by phenotypic recurrent selection in 2 North Carolina experimental lines was evaluated at Tucson, Ariz. Each cycle of selection showed improved resistance, and a highly satisfactory level, comparable to that of Moapa and Lahontan, was obtained in the third cycle. One hundred twenty-nine highly resistant plants from the third cycle of selection were returned to the breeder. Progress in transferring spotted alfalfa aphid resistance from Lahontan to Uinta alfalfa by the backcross method was also evaluated at Tucson. Resistance after the third backcross was not as high as desired, but can be satisfactorily improved in a generation or two of recurrent selection. Partial loss of resistance to stem nematode occurred during selection for aphid resistance among the backcross progenies.

Nearly 400 breeder-selected alfalfa clones from a Nevada-Pennsylvania program to develop new disease-, insect-, and stem nematode-resistant varieties were screened for resistance to spotted alfalfa aphid at Tucson. More than half of the clones were rated sufficiently resistant for continued use in the program. One hundred selfed progenies of the California high forage yielding clone, P-2, were screened for resistance to the spotted alfalfa aphid. This clone has only modest aphid resistance, but six progenies were highly resistant.

In tests at Lincoln, Nebr., observing the behavior of the spotted alfalfa aphid under conditions of free choice between resistant, susceptible, and non-host plants it appears that the mechanism of resistance is non-preference rather than antibiosis. Non-preference has been regarded by many workers as not being an important mechanism of resistance. In the light of the present findings it appears that the main problem is that of proper classification.

2. Pea Aphid. Emphasis in the alfalfa screening program at Lincoln, Nebr., has continued to be placed on finding combined resistance to the spotted alfalfa aphid and the pea aphid. Nebraska Synthetic 27 is continuing to perform well and is being used as a standard in tests for combined resistance to these two aphids.

At Poznan, Poland, (P. L. 480 project E21-ENT-9) no antibiosis to the pea aphid was observed in 4 European varieties of alfalfa, Medicago sativa, although there were slight differences in rate of development. Aphids placed on M. lupulina showed some reproduction for the first few days but all aphids died within 16 days and none of the nymphs reached maturity.

3. Lygus Bugs. Over 1200 plants representing 40 alfalfas of diverse origin were screened for resistance to lygus bugs in special field plantings at Mesa, Ariz. Two hundred twenty-three plants were selected for antibiosis or tolerance to these pests on the basis of visual observation. The most

promising material was found among progenies of a cross between a selection from Sirsa No. 9 and a selection from African. Other varieties contributing to the new pool of promising material were Hairy Peruvian and Lahontan.

4. Alfalfa Seed Chalcid. At Mesa, Ariz., over 1,000 additional plants from various alfalfas were screened for resistance to the alfalfa seed chalcid, and the number selected as having promise of adequate resistance to this pest was increased from 18 to 30. This number is about one percent of the plants screened over the past 4 years.

When single racemes of both susceptible and resistant plants were caged together and exposed to chalcids, a marked difference in seed infested in the two racemes was maintained, and the percent of seed infested in both racemes was higher than when susceptible and resistant racemes from the same plants were exposed in separate cages.

At Beltsville, Md., a new technique for testing for larval survival drastically reduced the variation obtained in previous tests, and significant differences were found among Medicago species and related genera in one test, and among 17 selected alfalfa clones in another test. Coefficients of variation in 3 tests were 21, 13, and 15%.

Over 1300 plants grown from seed of 33 plant introductions were screened in the laboratory. On the basis of egglaying in relation to stem diameter, 12 plants were selected as resistant.

Eighteen clones from the second cycle of recurrent selection for resistance to larval damage in the field were tested in the laboratory for egglaying preference. Most of these had low egg counts and 7 were equal to or better than the check (142 Belts.), a clone previously selected for low egglaying.

6. Egyptian Alfalfa Weevil. About 1000 plants in the nursery at Mesa, Ariz., were visually rated for damage by the Egyptian alfalfa weevil, and 123 were selected as promising for resistance. A high percentage of progenies of crosses between a number of Hairy Peruvian selections and a selection from Sirsa No. 9 were free of weevil injury. Thirty promising plants were also selected from a special nursery at Yuma, Ariz., and from several farmers' fields.

7. Sweetclover Weevil. Research at Lincoln, Nebr., testing Melilotus species for sweetclover weevil resistance showed that M. infesta is nearly immune and verified reports by Minnesota workers that M. sulcata possess a fair degree of resistance. Some selections were made from M. polonica which appear to have an intermediate level of resistance. This possible resistance in polonica is important because, even though this level of resistance is way below that in infesta or sulcata, polonica crosses readily with the commercially acceptable alba, while infesta and sulcata do not. In preliminary studies with grafts of M. infesta on M. officinalis there is some evidence that the resistance factor may pass across the graft into the

susceptible plant, indicating that grafting may provide a means of studying the nature and mechanisms of resistance.

H. Insect Vectors of Disease

1. Vectors of Red Clover Root Rot. Studies made at University Park, Pa., on persistence of red clover showed that insecticides extended the life of plants into the third harvest year whereas fungicides did not. When red clover was grown in the absence of root-feeding insects in pots in the greenhouse, taproots and crowns deteriorated in the second or third year, but the plants continued to live by producing adventitious roots. Adventitious roots produced in field plants were too small for borer attack, but in unsprayed plots the roots were consumed by Sitonid larvae about as fast as they were produced.

2. Vectors of Alfalfa Mosaic Virus. At Poznan, Poland, (P. L. 480 project E21-ENT-9) the pea aphid proved to be an efficient vector of alfalfa mosaic virus in studies with several common alfalfas (Medicago sativa). It was much less efficient in transmitting this virus to M. lupulina, infecting only 4 out of 100 plants in the test. Test feeding periods of 1 and 5 minutes produced a higher rate of transmission than periods of 15 and 30 seconds.

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AREA NO. 6. SOYBEAN AND PEANUT INSECTS

Problem: Soybeans and peanuts are severely damaged by several insect pests in the different areas where these crops are grown in the United States. The increasing concentration of acreage in soybeans and possibly the adaptation of native insects to this crop are resulting in more varied and more serious insect problems. In the absence of specific support for research on soybean insects, some shifts in emphasis have been made to investigate some of the problems. However, basic information is lacking on the biology of many of these pests and on the extent and nature of damage they cause to these crops. Such information is needed to serve as a foundation for the development of satisfactory control methods. Some insecticides, although highly effective in controlling insects on soybeans and peanuts, cannot be used because they leave harmful residues. Further, certain insects have developed resistance to insecticides that are currently recommended. For the immediate future, there should be continued effort to find insecticides that can be used safely and that give effective, economical control of all species of insects attacking these crops. For more desirable long-range solutions to the problems, more attention needs to be given to nonchemical control methods, with particular emphasis on insect-resistant crop varieties and biological control agents and the exploration of new chemical approaches such as attractants and repellents.

USDA AND COOPERATIVE PROGRAMS

The Department has a limited program involving basic and applied research on the insect problems of peanuts and soybeans directed toward developing efficient and economical control methods. The program is cooperative with State and Federal entomologists, agronomists and chemists. Studies on soybean insects are conducted at Columbia, Mo., and on soybean and peanut insects at Tifton, Ga., in cooperation with the Missouri and Georgia Experiment Stations.

The Federal scientific effort devoted to research in this area totals 1.5 professional man-years. Of this number 0.3 man-year is devoted to basic biology; 0.3 to insecticidal control; 0.5 to insecticidal residue determinations; and 0.1 to biological control; 0.1 to varietal evaluation for insect resistance; 0.1 to insect vectors of diseases and 0.1 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The States have an active program of research on soybean and peanut insects.

On soybeans, research is in progress to determine the amount and type of injury caused by various species of insects. Life histories and habits are studied under varied temperature and humidity conditions in the laboratory. Periodic field surveys are conducted to determine variations in seasonal

population levels of insects on soybeans and other host plants. Control treatments are applied at different times through the season to establish population levels necessary to cause significant damage.

Peanut insect research is concerned with seasonal history and habits of insect pests, determining economic infestation levels, chemical and cultural control and plant resistance studies. Biological information is being obtained as a basis for developing control programs. Rearing methods have been worked out for the most damaging species. Pests which appear sporadically are being studied to determine the factors responsible for outbreaks and the extent of injury they cause. Chemical controls and effects of tillage, irrigation and other management practices are evaluated under field conditions. The appearance of resistance in the southern corn rootworm to commonly used insecticides has necessitated intensification of nonchemical control research. Extensive comparisons of peanut introduction lines are being made and plants which exhibit resistance to insects are selected for further study and possible use in breeding programs.

There are 3.4 man-years devoted to soybean and peanut insect research in the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Soybean Insects. Broad-headed bugs, Coriscus eurinus and C. pilosulus, infested several fields of soybeans at Columbia, Mo., and fed extensively on the pods in the latter part of the 1963 season. Complete cycle from egg to egg required about 50 days. These bugs overwinter as eggs which are laid on the ground in the fall. Adults of both species were found from June 10 to mid-November.

The larvae of the sciarid fly, Sciarus sp., fed extensively on the roots of soybeans in the laboratory. The life cycle required approximately 20 days. This insect is a potential pest of soybeans, particularly in the spring in locations where the soil is moist.

At Tifton, Ga., the mean life cycle of the lesser cornstalk borer associated with soybeans and cowpeas was 43.1 days. Eggs hatched after 3 days incubation, larvae pupated in 19.6 days, pupation averaged 10.2 days, and mated female moths live 10.3 days. Unmated moths, both male and female, lived an average of 22.3 days. Adults are most active in the field on warm still nights when temperatures are above 80° F. Copulation and oviposition take place in darkness. Females deposited an average of 125.7 eggs each. Laboratory-confined moths failed to copulate when temperatures were 70° F. or below.

2. Peanut Insects. Cooperative investigations in 1963 with the Crops Research Division at Tifton, Ga., were made on the effect of insect pollinators in natural crossing in breeding nurseries in relation to producing pure peanut seed stock. When flowering peanut plants were caged to exclude solitary bees, outcrossings did not occur.

B. Insecticidal Control

1. Lesser Cornstalk Borer. Ten insecticides that have shown effective control of the lesser cornstalk borer attacking seedling soybeans and cowpeas were retested in 1963. All were applied in granular form at 2 lb. per acre in an 8-inch band over rows of seedling cowpeas in the two-leaf stage. All gave good control. Listed in the order of effectiveness were trichlorfon, AC 43064, ethion, diazinon, endrin, endosulfan, fenthion, carbophenothion, phorate, and Di-Syston.

C. Biological Control

One new parasite species, Chelonus (Microchelonus) n. sp. was collected at Tifton, Ga., in 1963. It contributed significantly to total insect parasite activity on the lesser cornstalk borer. Total parasitism by several species of insect parasites exceeded 50% in a number of samples of field populations. Parasite species collected to date in Georgia include Telenomus (Telenomus) n. sp., Chelonus (Microchelonus) n. sp., Pristomerus pacificus melleus, Orgilus n. sp., Stomatomyia floridensis, Bracon mellitor, and Plagiprospherysa parvipalpis.

D. Varietal Evaluation for Insect Resistance

1. Soybean Insects. At Columbia, Mo., over 100 plant introductions and experimental varieties of soybeans were evaluated in a field cage 12'x6'x60' for damage by the green stink bug, Acrosternum hilare. Density of bugs in the cage was one per square foot. Damage by the bugs in general was heavier for the later maturing soybean varieties. However, several varieties within each maturity group were damaged significantly less than the mean of that group.

E. Insect Vectors of Diseases

1. Soybean Yeast Spot. Field and laboratory tests at Columbia, Mo., with several species of Pentatomidae clearly indicated that Euschistus servus, Thyanta custator, Euschistus tristigmus can transmit yeast spot disease of soybeans in the field. Previously, Acrosternum hilare had been determined to be a vector. No evidence was found to involve Cosmopepla bimaculata and Peribolas lumbularius in the transmission of the disease. Data on E. variolarius and E. euschistoides are still incomplete.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

Hammons, Ray O., Krombein, K. V., and Leuck, D. B. 1963. Some bees (Apoidea) associated with peanut flowering. Jour. Econ. Ent. 56:905.

AREA NO. 7. CORN, SORGHUM AND SMALL GRAIN INSECTS

Problem: Many species of insects cause losses amounting to millions of dollars annually to corn, sorghum, and small grains. It is estimated that 25 species of insects cause an annual loss of $900 million to corn alone. The European corn borer and corn earworm are two of the most destructive insects in the country, and corn rootworms are serious pests of corn. Armyworms attack corn and small grains. In certain years the greenbug causes widespread losses to wheat, barley, and oats in the Central and Southeastern States, and the Hessian fly and wheat stem sawfly annually damage the wheat crop in certain areas. Recently, the sorghum midge has become a more important pest of sorghum in the Southwest. The cereal leaf beetle, first identified in the United States in 1962 from Berrien County, Mich., now occurs in 68 counties in Michigan, Indiana, and Ohio, and is a threat of unknown proportion to small grain crops. Such examples of the destructiveness of insects to corn, sorghum, and small grains point up the need for extensive research that will lead to the development of adequate means for the control of these important crop pests. Progress has been made toward the solution of some of the insect problems encountered in the production of grain crops but more effective, more economical, and safer insect control measures are needed. Research is essential to find insecticides that can be applied to grain crops, that will not leave residues harmful to animals consuming the feed, that will not be a hazard in milk and meat, and that will not be detrimental to beneficial insects or to fish and wildlife. The appearance of resistance to certain insecticides in several grain insect pests stresses the need for basic information to overcome this problem. Additional emphasis should be placed on research to develop crop varieties resistant to insects and on biological and cultural control methods. New approaches to insect control, such as sterilization techniques and attractants, require expanded investigation. Research is also needed on insect vectors and the role they play in the dissemination of important plant diseases. The heavy losses in oats, wheat, and barley due to barley yellow dwarf virus, and in corn due to stunt diseases recently found in Ohio and several Southern States, indicate the importance of research in this field.

USDA AND COOPERATIVE PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on Hessian fly, wheat jointworm at Lafayette, Ind.,

and Manhattan, Kans; cereal leaf beetle at Lafayette, Ind., and East Lansing, Mich.; aphids and mites attacking small grains at Stillwater, Okla., Brookings, S. Dak., and Tifton, Ga.; wheat stem sawfly at Fargo, N. Dak., Brookings, S. Dak., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and Lafayette, Ind.; fall armyworm, pink scavenger caterpillar, and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. Dak., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. Dak.; southwestern corn borer at Stillwater, Okla., and State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm, and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and insect transmission of grain diseases at Manhattan, Kans., and Brookings, S. Dak. Research to evaluate improved equipment for application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. Work on corn rootworms is being conducted at Brookings, S. Dak. Additional research is being conducted under ARS contracts on the biology and control of the cereal leaf beetle with Michigan State University, soil insects attacking corn with the University of Nebraska, and vectors of corn stunt virus with Mississippi State College.

The Federal scientific effort devoted to research in this area totals 37.5 professional man-years. Of this number 9.7 is devoted to basic biology, physiology, and nutrition; 4.5 to insecticidal and cultural control; 3.0 to insecticide residue determinations; 3.6 to biological control; 2.8 to insect sterility, attractants and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 10.7 to varietal evaluation for insect resistance; 1.3 to insect vectors of diseases; and 1.4 to program leadership.

Certain phases of this research are contributing to regional research project NC-20 "Factors Influencing European Corn Borer Populations". A P. L. 480 project, E8-ENT-1, "Population Dynamic Studies on Calligypona pellucida (F.) and the Nature of Injuries Caused by This and Other Leafhopper Species (Fulgoridae) on Cereals, Especially Oats and Spring Wheat" is underway at the Agricultural Research Centre, Department of Pest Investigation, Helsinki, Finland. Another P. L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of The Disease" is being conducted at the Hebrew University, Rehovoth, Israel. A7-ENT-25 in India is concerned with "Research on Insect Pests of Maize With Special Reference to Stalk Borers".

PROGRAM OF STATE EXPERIMENT STATIONS

Extensive research is in progress in the States on insects affecting corn, sorghum, and small grains. Biological information is being obtained on a variety of pests. Data acquired include overwintering habits, time of emergence, food habits, interspecies competition, mating, oviposition, migratory, and dispersion habits and longevity. This information is being used to develop methods of predicting the incidence of pest outbreaks.

Ecological studies are being performed to determine the effects of temperature and other factors such as plant growth, soil conditions, and crop sequence on population levels. The influence and efficiency of various natural enemies are also being evaluated.

Cultural control techniques including the effects of fertilizer applications, soil management practices, time of seeding, irrigation, stubble mulch and grazing receive their share of attention.

Experimental insecticides are tested for their effectiveness. Samples of treated crops are analyzed for harmful residues. Insecticide treatments are also used to determine the degree of infestation which crops can tolerate before control becomes necessary.

Research on artificial rearing is performed to develop methods for providing insects for year round study and for uniform infestation in plant resistance work. Plant varieties, hybrids, and lines are evaluated in the field and in nursery plots for their resistance to insect attack. Crosses are made to increase resistance levels and biological, physiological, and chemical studies are conducted to determine the nature of the resistance.

Vectors of plant diseases are studied to increase our knowledge of insect-plant relationships which could lead to the control of the vector and, consequently, the disease. The roles of alternate host plants and vector seasonal life history and flight patterns are being studied. The effect of the disease organism on vector biology, morphology, and cytology is investigated.

There are 29.0 man-years devoted to research on corn, sorghum, and small grain insects in the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Corn Insects. European corn borer populations showed a substantial increase in 1963 over 1962. 1963 borer populations in Boone County, Iowa, reported as average borers per acre, were as follows: Early spring 3,014, late spring 2,050; first brood 2,958, second brood 17,250; and post-harvest 9,075. Populations for 1962 were 4,479, 3,187, 1,800, 12,600, and 4,857, respectively. The high survival of second-generation borers and large number of borers going into hibernation could present a serious corn borer problem in 1964.

Population studies in which Missouri, Minnesota, and Iowa cooperated, indicated that strains or biotypes, probably associated with ecological conditions, have developed in the European corn borer.

A laboratory diet was developed at Ankeny, Iowa, which apparently contains the necessary nutrients and vitamins for normal development of the European corn borer. The development of this efficient diet is considered to be a major breakthrough in corn borer rearing and has lead to the development of mass-rearing techniques which have lowered production costs to less than one cent per borer - including diet materials and labor. Colonies reared on this diet have reached the eleventh generation.

At Brookings, S. Dak., trehalose has been isolated and identified as an important component of the hemolymph in the three grasshoppers, Melanoplus differentialis, M. bivitattus, and M. femurrubrum, constituting more than 90% of the free, neutral sugar in the eggs.

Studies conducted at Brookings, demonstrated that western corn rootworm eggs will hatch very slowly without any cold treatment to break diapause; however, a cold period before incubation speeds up egg development and hatching considerably. A cold period of 116 days causes egg hatching to commence after 16 days of incubation and to be essentially completed in 45 days. It was learned that mating can occur between different species of corn rootworms and that the resultant offspring resemble the western corn rootworm. These results help explain why populations of northern corn rootworms have appeared to be low in areas heavily infested with western corn rootworms.

Surveys conducted in 1963 in Alabama, Florida, Georgia, North Carolina, Mississippi, and South Carolina, indicate that the corn earworm caused an estimated $3,400,000 loss to dent corn. Other insects causing widespread damage were pink scavenger caterpillar, rice weevil, and fall armyworm. The European corn borer was found in 48.2% of the fields surveyed in North Carolina. Corn stunt virus disease was found in 5 fields in Georgia. The number of counties infested with the southwestern corn borer in Mississippi increased from 47 in 1962 to 70 in 1963; in Alabama, from one to 15 counties; and in Tennessee, from 15 to 25 counties.

A far infrared theory of communication and location between individuals of the opposite sex of the corn earworm moth was developed at Tifton, Ga. The corn earworm is capable of raising its thoracic temperature from 1° to 8.8° F. above the ambient temperature, and the sphingid, Lapara conifernarum, to 17.8° above the ambient temperature. The far infrared output associated with the temperature differential was calculated to lie between 9 and 11 microns. Tests indicate that far infrared radiation would be a much more efficient method of location between sexes over great distances than would be attraction due to scent. Earworm antennae have organs with measurements and configurations of FIR resonators. Configurations useful in picking up other wave lengths were also present and may be tuned for intermediate infrared pickup of emitting molecules of sex releasers or feeding and host plant substances. Histological examination of ommatidia of the adult corn earworm at Tifton indicates that the compound eye is a high absorber of far infrared radiation and is of such a configuration that it could orient to hot or warm spots of longwave infrared radiation in total darkness.

A biological study of the southwestern corn borer conducted at Stoneville, and State College, Miss., indicated that this insect completed three generations and a partial fourth in 1963. Very few of the first-generation larvae girdled plants and entered diapause, but 23% of the second generation, and 95% of the third generation did. The females outlived the males and laid an average of 291.2 eggs per female, most of them on the first night of the oviposition period. Borers reared on artificial diet required an average of 37 days to complete the life cycle from egg to adult; those reared on the corn diet required 34.4 days. Borers were found in sudangrass, sweet sorghum, and johnsongrass.

At Stillwater, Okla., feeding honey or sucrose solutions to moths of the corn earworm and fall armyworm resulted in significant increases in oviposition. The average number of eggs per corn earworm female, for example, was 4 when no food was provided, as compared with 406 and 503 when fed 10% and 50% honey, respectively, and 456 and 545 when fed 10% and 50% sucrose, respectively.

2. Small Grain and Sorghum Insects. Surveys conducted at Lafayette, Ind., indicated that 6-1/2 million acres of Hessian fly resistant wheat were grown in 27 States during the 1963-64 crop year, an increase over last year of 2 million acres. This represents a savings of millions of dollars to the farmer as heavy infestations of fly have been known to cause losses as high as 20 to 30 bushels per acre. The breeding and release of these resistant varieties was accomplished through the cooperative efforts of researchers from State experiment stations and the Crops and Entomology Research Divisions.

At Lafayette studies of the racial composition of field populations of Hessian fly continue to show large numbers of Race B individuals in areas where wheat varieties having the W38 resistance have been grown for a considerable length of time. Progenies from infested fields in which the resistant variety Monon was grown showed 10% of the progenies to be Race A phenotype, 77% Race B, 0% Race C, and 13% Race D, indicating that the W38 resistant varieties grown in these areas favored the development of Race B and prevented the development of Races A and C. The number of Race D individuals suggests that interracial crosses between Race B and C individuals occurred, producing Race D individuals, which can survive on the W38 wheats whereas Race C individuals cannot and did not continue to survive.

At Lafayette, a study was conducted to determine the inheritance of resistance of the 28 chromosome Hessian fly resistant Durum wheat PI 94587. Data on F_3 families from crosses of PI 94587 and the susceptible Durum wheats CI 113160, CI 7805, and Purdue Accession 186, evaluated under Hessian fly infestations, indicate that 4 dominant factors condition the resistance to Hessian fly in PI 94587. In addition, monosomic analyses of wheat to locate chromosomes responsible for Hessian fly resistance were continued. Analyses of F_1, F_2, and F_3 families from crosses between the

Hessian fly resistant wheat, Purdue 4835 A4-6-3, and 21 suceptible Chinese monosomics indicated chromosome 5A(1X) to be responsible for the single gene resistance of this PI 94587 derivative.

At Tifton, Ga., studies on physical environmental factors necessary for grain aphids to initiate and maintain flight indicate that the greenbug and the corn leaf aphid can maintain flight only after the air temperature exceeds 65° and 63° F., respectively.

The ecology and migration studies of small grain aphids at Brookings, indicate that Rhopalosiphum padi, a vector of barley yellow dwarf virus, overwinters as far north as South Dakota. Reestablishment of populations of the other vector species, was by aerial transport from areas to the south. Populations of R. maidis and R. padi have successfully fed and reproduced over two week periods on artificial diets.

At Tifton, Ga., oats planted at 9 different densities, 1, 2, and 4 bushels per acre and row width spacings of 3, 6, and 12 inches were investigated for numerical differences in arthropod populations. Phytophagous arthropods per plant were the lowest in the planting designs provided by 2 bushels per acre sown in 3-inch rows and by 4 bushels per acre sown in 6-inch rows. The number of parasites and predators per arthropod was the highest at 1 bushel per acre sown in 12-inch rows followed by 2 and 4 bushels per acre sown in 2- and 6-inch rows, respectively.

In the streak-mosaic infected area of Kansas, 46.4% of the mites collected at random from volunteer wheat plants, 15.9% of those from seeded wheat, and 3.2% of those from grass plants, were viruliferous, indicating that wheat curl mites on volunteer wheat are an important source or reservoir of wheat streak mosaic.

Studies conducted at Brookings, S. Dak., indicated the effect of relative humidity on hatching of wireworm eggs. Eggs reared at 100% R. H., hatched in 167 hours, and at 75% R.H. in 193 hours, the number of hours required for hatching increasing as the relative humidity decreased.

A method for mass rearing the false wireworm (Embaphion muricatum) has been developed and used in the production of approximately 30,000 larvae. Cannibalism and disease are not problems when sufficient food is available. The development of continuous laboratory cultural methods for false wireworms should provide an excellent source of soil-inhabiting insects for basic research studies.

B. Insecticidal and Cultural Control

1. Corn Insects. At Ankeny, Iowa, 17 insecticides were tested in granular formulations against first-generation European corn borer larvae. Telodrin, diazinon, Bayer 25141, DDT, 1-bromochlordene, endrin, Union Carbide UC-8305, Bayer 38156, Bayer 37289, Bayer 39007, Stauffer N-2790, and phorate gave better than 85% control. Of the 11 compounds tested for control of

second-generation larvae, only Telodrin, endrin, Bayer 25141, diazinon, and DDT gave 85% control. DDT was more effective for control of first-generation larvae than any other compound tested in spray formulations. Of several compounds tested for systemic control of corn borer larvae on corn, American Cyanamid E.I. 47470 was the most effective. Other compounds which demonstrated systemic activity were American Cyanamid E.I. 47826, and E.I. 47938, Niagara 9203, and Bayer 39007.

Eleven insecticides were evaluated for control of the corn earworm at Tifton, Ga. Shell Compounds 4072, SD 8211, SD 8447, SD 8448, Bayer 47940, Bayer 44646, Bayer 41831, trichlorfon, and DDT at 2 pounds per acre in sprays made with wettable powder gave equal or better control than a standard DDT emulsion spray applied at the rate of 2 pounds of DDT per acre. Cynem and Vapona at 2 pounds per acre gave significantly poorer control than did the DDT standard.

At State College, Miss., good control of corn earworm was obtained with carbaryl at the rate of 1-1/2 pounds per acre and with Telodrin at 2 pounds per acre on sweet corn.

Tests to compare the effectiveness of endrin, carbaryl, and Telodrin for the control of the southwestern corn borer on dent corn were conducted at 3 locations in Mississippi. Telodrin gave best control at one location and endrin gave best control at the other two. At State College double disking in December with a tandem disk was effective in controlling the southwestern corn borer, whereas uprooting stalks with a middle buster had little effect on borer populations. Date of planting studies with dent corn, indicated that southwestern corn borer damage can be reduced by early planting.

Dosage-mortality curves determined for corn rootworm samples obtained in various parts of the corn-rootworm infested area indicated that resistance to aldrin was present in western corn rootworm populations in western Iowa, southeastern South Dakota, southern Minnesota, and northwestern Missouri during 1963. Aldrin-resistant populations of northern corn rootworm were found in widely scattered areas of Iowa, Minnesota, Wisconsin, and Illinois.

Studies conducted at Brookings, S. Dak., showed that resistant western corn rootworm, treated with high dosages of aldrin in the laboratory, formed about 1/12 as much dieldrin as the susceptible strain one hour after treatment. Approximately twice as much dieldrin was formed by the susceptible strain thereafter. The resistant strain metabolized 10-30% of the applied aldrin to dieldrin. Thus, the resistance mechanism in western corn rootworm appears to involve the epoxidation chemistry of the aldrin-dieldrin complex. These data also indicate that aldrin *per se* is not the toxicant.

2. Small Grain and Sorghum Insects. Seventeen materials were tested for brown mite control in Oklahoma. The following 8 compounds gave better (93-99%) control than parathion (87%); SD-9129, Meta-Systox, dimethoate,

Bidrin, Di-Syston E.C., carbophenothion, Bayer 25141, and fenthion. Three chemicals equal to parathion were SD-7438, Stauffer N-2404, and phosphamidon. The following 5 materials were less effective (0-79%) than parathion at the dosages used: Bayer 37289, UC-20047, tetrasul, tetradifon, and Morestan.

Of 13 insecticides screened against the greenbug in the laboratory at Stillwater, Okla., SD-9129, Bidrin, and endothion were very effective. These three insecticides at 1/4 and 1/8 lb. per acre were tested against the greenbug in a combined field and laboratory experiment. SD-9129 gave complete protection to Triumph wheat for 15-17 and 10-15 days at the respective rates. Bidrin at both rates protected the plants for 7-10 days, and endothion for 3-6 days. Parathion, which was used as a standard, controlled the insect for 2-3 days. Of 7 materials tested in the field, SD-9129 proved to be the best, giving 100% control of the greenbug for 16 days at both 1/4 and 1/8 lb. of toxicant per acre. Bidrin, endothion, parathion, and phosphamidon also gave satisfactory control.

Insecticidal phytotoxicity studies at Stillwater involving 5 sorghum hybrids and their parental lines and 5 recommended insecticides, showed marked differential leaf injury and yield reduction when the chemicals were sprayed on plants in the medium- and hard-dough stage of development. In general, naled and methyl parathion caused severe leaf injury and yield reduction in all entries except Combine 7078, RS-610, and Caprock. These 3 varieties were tolerant to all insecticides tested. Toxaphene caused less than 10% leaf injury and relatively low yield reduction. Entries treated with carbaryl and endrin were not significantly different in leaf injury and yield from the untreated checks. Phytotoxicity apparently was caused by the active ingredient in the sprays, and not by the solvent.

Observations made on sorghum midge damage in the Amarillo-Plainview-Lubbock area of Texas indicated no damage in the early-planted fields(May). Damage was observed only in a few isolated late-planted fields or in purposely late-planted nursery plots. Although the latter were sprayed with parathion and toxaphene, infestation and damage were not controlled.

Seventy insecticides were evaluated in laboratory tests against larvae of the cereal leaf beetle at Lansing, Mich. In general, the carbamates were the most effective. In some field tests there was apparently an excessive kill of lady beetles when carbaryl and Guthion were applied. Fourteen insecticides were tested in the field on wheat and oats. Six which were very effective against the pest were dieldrin (1/2 lb. per acre), lindane (1/2 lb.), carbaryl (1 lb.), endrin (1/4 lb.), Guthion (1/2 lb.), and malathion (1 lb.).

C. Insecticide Residue Determinations

1. Residues on Corn. At Ankeny, Iowa, applications for first-generation borer control of 1-bromochlordene sprays deposited residues which 1 day after treatment contained 1.5 to 3.1 ppm 1-bromochlordene and 0.45 to 0.57

ppm of its epoxide, while the residues from granular formulations contained 10 to 24 ppm of 1-bromochlordene and 0.10 to 0.18 ppm of its epoxide. When 1-bromochlordene was applied as sprays or granules for second-generation borer control, the initial deposits varied from 0.5 to 1.8 ppm and there was no difference between formulations. Fifty-five days after treatment, residues as great as 0.39 ppm of 1-bromochlordene and 0.46 ppm of the epoxide were found. Sprays of 1-bromochlordene to sweet corn left residues of 0.2 to 0.8 ppm of 1-bromochlordene and 1 to 1.8 ppm of the epoxide on the husks and cobs 1 day after final treatment. Seven days after final treatment the husks and cobs contained <0.1 ppm of 1-bromochlordene and 0.3 to 0.48 ppm of the epoxide. No residues (less than 0.01 ppm) of either the 1-bromochlordene or the epoxide were found in the kernels from corn plants treated with 1-bromochlordene.

At Ankeny, in May 1953, plots were treated with emulsion sprays containing dieldrin (2.37 lb. per acre), aldrin (2.06 and 4.89 lb. per acre) and heptachlor (2.03 and 4.07 lb. per acre). Soil residue data have been obtained from these plots at intervals from the time of spraying. Samples collected in April 1963 were analyzed for dieldrin and heptachlor epoxide residues by gas chromatography. Less than 0.1 ppm of heptachlor epoxide and less than 0.3 ppm of dieldrin were found in the soil.

Fields at the Ankeny, Iowa, Experiment Station were treated with 2 lb. of heptachlor per acre in alternate years since 1958. Samples of soil from these fields collected in June 1963 contained about 0.3 ppm of heptachlor epoxide. Soil from a field treated with heptachlor in the spring of 1963 contained 0.9 ppm of heptachlor as compared to 0.5 ppm of heptachlor in the soil from a field last treated in 1962.

A field in Iowa planted to corn has received a dosage of 0.8 lb. of aldrin per acre in the row at planting time each year since 1958. Samples of soil taken from the corn row in June 1963 contained 4.2 ppm of aldrin, while samples collected from between the corn rows at that time contained only 0.06 ppm of aldrin. The dieldrin residue in samples from both areas was 0.12 ppm.

The study of the uptake of Telodrin by different instars of the fall armyworm has been completed at Tifton, Ga. Insecticide residues were determined by gas-liquid chromatography and electron affinity detection, radiometrically, and by paper chromatography of C^{14} labelled Telodrin. The quantity of toxicant required internally to produce mortality could not be precisely determined for first instar larvae, although the range was 1.9 to 5.59 ppm. The lethal dose of Telodrin in the integument and internal organs of third instar larvae was 5.86 to 6.05 ppm, with approximately 3.5 ppm in the internal organs. There was no correlation between total lipid content and the lethal dose in individual full grown larvae, although there was an indication that mortality of full grown larvae was directly related to unsaturated fat content. No detectable metabolism of Telodrin occurred on or in the three larval instars examined under the conditions of these experiments.

At Tifton DDT formulated as an emulsion, dust, and granules was applied to sweet corn at the 1- and 5-day silk stage by means of conventional equipment and techniques at the recommended rate (2 lb. of DDT per acre) for controlling the corn earworm. Samples of the silks and ear tips were taken at several intervals during 8 days and the residues were determined by gas chromatography. Greater residues were found on silks and ear tips treated with granules than were found on silks and ear tips treated with dusts. Silks and ear tips treated with sprays had the least residues. Variations in the quantities of DDT deposited by dust and granular treatments, however, were about twice those of the spray.

An analytical method for determination of residues of Shell SD-8447 and its chlorine containing hydrolysis product in sweet corn plants and ears was developed by chemists at Tifton. The insecticide and the hydrolysis product chromatographed well in a stainless steel column containing silicon grease on chromosorb W. Both products were completely recovered from corn plants and ears by blending with hexane-acetone and 95% was recovered with hexane alone. Hexane solutions of the concentrated extracts were cleaned in a counter current distribution apparatus.

At Tifton chemists used electron affinity gas chromatography to study the behavior of 11 chlorinated insecticides in 8 types of soil under controlled laboratory conditions in order to provide a better basis for understanding and predicting the fate of such pesticides in the field. Lindane was the most susceptible to leaching, while p,p'-DDT was the most resistant of the insecticides. Generally, soils that were not deactivated with water lost less insecticide while those deactivated with water prior to the addition of insecticides lost the most. Degradation of insecticides was markedly diminished in wet soils. The presence of organic matter in soils (6% or more) greatly inhibited leaching, volatilization, and degradation of the insecticides tested.

2. Residues on Small Grain and Sorghum. Granular formulations of heptachlor and heptachlor epoxide were applied with seed wheat at rates of 1/4 to 1 lb. of the insecticide per acre for sawfly control at Conrad, Mont. Residues of heptachlor epoxide were found in green wheat 55 days after planting in the plots receiving the higher dosage. No residues were found in the mature grain. Straw samples contained heptachlor and heptachlor epoxide residues, the amount increasing in general as the dosage increased.

In Oklahoma, diazinon was sprayed on RS-610 grain sorghum in the dough stage at the rate of .75 lb. in 12 gallons water per acre on September 20, 1963. Four-pound samples each of grain and foliage were taken for residue analysis on September 20, 23, 26, and October 4. Residues in ppm on the respective dates were for the grain: .46, .06, .05, and .05; and for the foliage, 3.5, .13, .22, and .05. For untreated grain and foliage the residue was .05 ppm.

D. Biological Control

1. Corn Insects. At Ankeny, Iowa, various tests with the bacterium, Bacillus thuringiensis, have continued to point out its usefulness in the control of the European corn borer. In field tests, granular formulations of the bacterium gave control of the borer equal to that of recommended insecticides for the third year. Spray formulations, however, gave inferior results. Laboratory tests with an encapsulated B. thuringiensis formulation were sufficiently promising to warrant field tests with the material.

A bacteriophage (virus-attacking bacteria) was isolated from one European corn borer larva, and from B. thuringiensis which had been irradiated with ultra violet light. Preliminary laboratory tests with bacteriophage indicate that it will have little effect in reducing borer kill by B. thuringiensis in the field, although it may slow mortality of the borers.

The continuing survey of field-collected borer larvae from 7 States for infection with the protozoan, Perezia pyraustae, indicated the rate of P. pyraustae infection was higher than in the previous year.

The virus-like disease found in field-collected corn borers did not manifest itself in large numbers of larvae during the year. Only a few individual specimens exhibiting the disease symptoms were collected. Electron micrographs indicate the probability of a non-inclusion virus attacking the fat body. To date, laboratory attempts to transmit the disease have failed to produce symptoms in treated larvae.

The distribution and abundance of exotic parasites was determined in 14 States. Parasitism had increased in 5 States, remained the same in one, and was down in 8 States. A total of 10,451 larvae were processed. Of the standard collections, South Dakota had the highest parasitism (21%), while North Dakota was lowest with no parasitized borers in the collection.

Preliminary tests with Tachinidae and Ichneumonidae parasites imported from India in connection with P. L. 480 project indicated that 2 tachinids, Drino sp. and Tachinid sp. "A", and 2 ichneumonids, Eriborus sp. and Ecphoropsis sp. would parasitize the corn earworm in the laboratory. A large culture of Drino sp. was established for possible field release.

A survey of native parasites of the corn earworm and fall armyworm on corn in Georgia revealed that Microplitis croceipes was the most important parasite of corn earworm larvae feeding in whorl stage corn, but was not found in larvae feeding in the ears of corn. Fall armyworm larvae collected from whorls of corn in early August exhibited 70% parasitism by Chelonus texanus, an egg-larval parasite.

At Tifton, Ga., the nuclear polyhedrosis virus of the corn earworm discovered at Brownsville, Tex., was used in field trials for comparison

with DDT and to determine the best concentration of virus for protection of sweet corn. Preliminary tests indicate that the virus at a concentration of 250 larval equivalents per acre gave control of the corn earworm comparable to 2 lb. of DDT per acre. In other tests conducted at Tifton, a granulosis virus of the fall armyworm obtained in South America was infective after 7 years of storage. Histopathological studies indicated that the fat body is the only tissue attacked by this virus and that infected larvae usually die in the last instar regardless of age at time of treatment.

2. Small Grain and Sorghum Insects. At Lafayette, Ind., Hessian fly infested material collected from six locations showed that high mortality of the fall generation was due to the chalcidoid parasite, Platygaster hiemalis. Total mortality of 4,412 isolated puparia was 69%. Forty-nine percent of the puparia were parasitized, 20% died from undetermined causes, and 31% produced Hessian fly adults. This parasite is considered to be of economic value in reducing spring infestations since it is the only parasite that attacks the fall generation of fly in any significant number.

Three kinds of parasitic wasps that kill the cereal leaf beetle have been discovered in Western Europe. From information currently available it is apparent that these parasites reduce the seriousness of outbreaks of the beetle in France and Italy. Colonies of one of the wasps have been released in LaPorte County, Ind., and the liberated parasites were observed to attack living larvae of the cereal leaf beetle.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Corn Insects. Cytological techniques were developed for studying spermatogenesis in the European corn borer and related species at Wooster, Ohio. Haploid chromosome counts of 31 were recorded for the European corn borer (Ostrinia nubilalis), smartweed borer (Pyrausta ainsliei), and lotus borer (P. penitalis). No differences were found in the chromosome morphology of these three closely related species.

A study was conducted at Ankeny, Iowa, on the morphological development of corn borer testes to determine at what stage radiation or chemosterilants should be applied to produce sterility. The testes can be easily found in 3rd instar larvae, and spermatogenesis begins in the 4th instar. All stages of spermatogenesis can be found in the 5th instar, including mature sperm. In the prepupal stage, the two testes fuse into a single "sack" containing 8 segments. By the time the larva has pupated nearly all spermatocysts have matured to sperm. Only mature sperm can be found in the adult testes. This evidence indicates that lethal gene mutations are most likely to be obtained if 4th and 5th instar larvae are irradiated with gamma rays, or are treated with chemosterilants. Irradiated or chemosterilant-treated pupae or adults will contain only killed or injured sperm.

Results at Ankeny suggest that male sterilization of the European corn borer may be obtained by irradiation of (a) 3rd and early 4th instar larvae, affecting only spermatogonia; (b) late 4th instar larvae, affecting spermatogonia and early spermatocytes; (c) half- to full-grown 5th instar larvae and early pupae, affecting all stages of spermatocytes, spermatids, and mature spermatozoa; and (d) adults, primarily affecting spermatozoa. Preliminary tests indicate that the sterilizing dosage is between 2,500 and 5,000 roentgens for 4th and 5th instar larvae.

Four different techniques for the treatment of the European corn borer with chemosterilants have been tested. These 4 methods are (1) injection of 5th instar larvae with 1 and 2 µl of 5% chemosterilant in water, (2) dipping pupae in 1-2 and 4% chemosterilant in acetone and water for 30 minutes, (3) topical application of 0.5 µl of 2.5-5% chemosterilant in acetone to virgin moths 0-24 hours after emergence, and (4) dipping 0-24 hour old virgin moths in 1-2% chemosterilant in water plus 0.1% Triton X-100. With the two chemicals tested (apholate and metepa) the dosages which induced partial sterility also caused some mortality and loss of vigor. However, the most promising of the methods is the adult dip method.

At Tifton, Ga., laboratory testing of extracts from virgin fall armyworm moths showed that a mating stimulant is produced near the 2nd and 3rd abdominal segments of the female moth. Attempts to recover the material from head, thoraces, or upper abdominal portions have been unsuccessful. The lure which induces typical copulatory activity in the virgin male has been extracted with ethyl ether and partially purified by silicic acid chromatography.

Also, at Tifton, laboratory-reared fall armyworm moths were sterilized when exposed to tepa-treated glass plates at rates of 10, 1, 0.5, and 0.25 mg per 100 square inches. Complete sterility was obtained in the 10, 1, and 0.5 mg treatments with only 1% hatch at 0.25 mg. Complete sterility was obtained in the male when fed 31.25 µg of tepa as compared to 3000 µg for apholate, in the female fed 62.5 µg of tepa as compared to 3000 µg of apholate. Treated laboratory-reared fall armyworm adult males were able to compete effectively with untreated laboratory-reared males for untreated females.

When field-collected moths of the armyworm (Pseudaletia unipuncta) were fed 62.5 µg of tepa suspended in a 10% sugar solution, egg hatch was completely eliminated. No apparent adverse effects were noted in either the frequency of mating of the females or in the number of eggs laid per female.

At Tifton an unidentified feeding stimulant for corn earworm larvae has been found in corn silks and sorghum heads. The stimulant is present in extracts of sweet corn silks fixed in anhydrous ether and extracts from ether-fixed sorghum heads in the early dough stage. It is relatively heat stable, nonvolatile, insoluble in ether, and soluble in water. No response by the larvae was obtained from leaf extracts. Techniques are not yet sufficiently refined to determine differences among corn inbreds in the response of larvae to the substance. There was no correlation of the

response with kernel resistance. Fall armyworm larvae did not respond to the substance.

In tests conducted at Brookings, S. Dak., during the summer of 1963, presence of a feeding stimulant for western and northern corn rootworm adults (Diabrotica virgifera and D. longicornis) was demonstrated in the kernel, pistillate branch, silks, leaves, and root of corn, and in squash blossoms. The highest concentration of the feeding stimulant, in extracts of plant parts tested, occurred in corn kernels. Olfactometer tests were conducted to determine if the three species of corn rootworm were attracted to plants by odor. Tassels, whorl leaves, silks, and ear tips from various varieties of field and sweet corn; blossoms, and leaves of squash; juice from macerated blossoms; and lyophilized extracts of corn and squash plants were evaluated. Northern corn rootworms responded positively to corn silks and extracts of them; western corn rootworms responded positively to extracts of corn silks and summer squash blossoms; and southern corn rootworms responded positively to corn silks and summer squash blossom extracts.

F. Evaluation of Equipment for Insect Detection and Control

1. Corn Insects. At Tifton, Ga., research was continued on an electrostatic duster in cooperation with the Agricultural Engineering Research Division. Positively charged DDT and carbaryl dust gave better earworm control than negatively charged or uncharged dusts of the same insecticides. There was no significant difference between the control obtained with negatively charged dusts and uncharged dusts. DDT emulsion spray gave better earworm control than any of the dust treatments. Research previously reported showed that plants dusted with positively charged and negatively charged particles had about 57% and 36%, respectively, greater residues than plants dusted with uncharged dusts.

At Tifton, agricultural engineers and chemists used simulated corn ears made from filter paper to study nozzles, gallonage, and pressure. Effectiveness was measured by determining insecticide residues. The data have not been completely analyzed; however, results to date indicate there was an average of 19.1% more deposit on the front side than on the back side of the 2-inch tip of the ears when they were oriented 90° to the row. Ears oriented with the row received essentially the same deposit on both sides.

G. Varietal Evaluation for Insect Resistance

1. Corn Insects. Investigations conducted at Ankeny, Iowa, on the effects of cytoplasmic factors for male sterility and fertility restorer sources on first-brood European corn borer resistance show that considerable variation is introduced when these factors are involved.

Inbred lines of corn developed by State and Federal corn breeders from the Southern Corn Improvement Conference area were tested at Ankeny for first-brood European corn borer leaf feeding. Of a total of 150 Southern inbreds

tested in 1963, 36.7% were as resistant to leaf feeding as the resistant check, and 18.0% were as susceptible as the susceptible check. A series of test crosses of maize races and varieties from Mexico, Central America, and the Caribbean Areas provided by The Rockefeller Foundation's Agricultural Sciences program in Mexico was tested for first-brood corn borer resistance. Conflicting results were obtained in some tests. However, promising sources of first-brood corn borer resistance were found among a group originating in Antigua.

Studies were conducted at Ankeny to obtain information on the progress made in the development of corn borer resistant hybrids during the past decade. The tests included old and new hybrids with known as well as closed pedigrees, obtained from commercial sources. Some plots were infested with corn borer egg masses while others (checks) were treated at weekly intervals with an insecticide during the first brood moth flight to prevent infestation. Wide differences in borer leaf-feeding ratings were found among the hybrids in the borer-infested plots. In general, the newer hybrids had more resistant leaf feeding ratings than the old hybrids.

Tests are being conducted in a corn borer nursery at Ankeny to obtain information on the genetic mechanism involved in corn borer resistance. An attempt was made to determine which chromosome arms(s) of the resistant line, B49, carries gene(s) for resistance to corn borer leaf feeding, using translocation stocks. (B49 X translocation stock) X WF9 may possess genes for resistance which differ from the genes of WF9 and/or M14 on the short arms of chromosomes 1, 2, and 4; and on the long arms of chromosomes 4, 5, 6, and 8. Crosses of (CI.31A X translocation stock) X WF9, grown in 1961, 1962, and 1963, and (CI.31A X translocation stock) X M14, grown in 1962, and 1963, indicate that inbred CI.31A carries a gene for resistance on the short arm of chromosomes 1, 2, and 4; and on the long arm of chromosome 4 and possibly 6.

Tests using 150 F_2's backcrossed to parental lines CI.31A (resistant) and B37 (susceptible) were conducted to obtain information on the relative importance of additive and dominance type of gene action present in the expression of resistance to corn borer leaf feeding. These tests showed that additive variance was approximately 4 times greater than the estimate of dominance variance, indicating that the additive variance was more important in the expression of the inheritance to corn borer leaf feeding.

In another test conducted at Ankeny five resistant lines (CI.31A, B49, MS1, HD225, and B46) and 5 susceptible lines (WF9, M14, B37, B14, and A297) were crossed in all possible reciprocal crosses to study the inheritance of corn borer leaf feeding resistance. B49 and CI.31A contributed the greatest degree of resistance to leaf feeding to their hybrids, HD225 contributed somewhat less, and MS1 and B46 contributed the least resistance when in hybrid combination.

Tests of inbred lines of field corn for resistance to the second brood of European corn borer were conducted at Ankeny during a 5-year period ending in 1964. Distinct differences have been found between inbreds. A study was initiated in 1963 to obtain information on relative yield losses of resistant and susceptible crosses as well as general information of the inheritance of resistance to second-brood corn borers. A total of 45 diallel crosses among 10 inbred lines were used for this study. Five of these lines had been selected as being resistant, B52, R101, HD2187, (41.2504B X $B14^3$)-10, and B55, and five were selected as susceptible, Hy, WF9, W22, Oh43, and M14, to a second brood infestation. The overall effects of second brood infestation were a reduction in yield of 5.3%, decreasing the mositure percent in the grain from 17.6% to 16.8%, and increasing the percentage of stalk lodging from 1.5% to 4.4%. The two lines, R101 and (41.2504B X $B14^3$)-10, seemed to be best in preventing yield losses under second-brood corn borer infestation in hybrid combinations.

An important phase of the resistance program at Wooster, Ohio, is screening inbred lines of dent corn, submitted by corn breeders from the Northern States of the North Central Region, for resistant germ plasm. In 1963 the Michigan Experiment Station submitted 644 inbred lines and 19 double cross hybrids. A total of 363 lines was derived from single crosses; 13.8% of these had a good degree of resistance. A total of 255 lines were mostly retest material, several of which have been selected for prolific characteristics; many of these lines have indicated a good degree of resistance to the corn borer in at least one previous test; 54.9% of these lines had a satisfactory degree of resistance. A total of 26 lines are used in Michigan certified hybrids; 30.8% of these lines had a good degree of resistance. Five experimental double cross hybrids which have shown a good degree of resistance for several years indicated a high level of resistance in 1963. Two of 14 Michigan certified hybrids had a satisfactory degree of resistance.

Corn borer establishment and survival was determined in a hydroponics study at Wooster of corn grown with three levels (50, 100, and 200 ppm) of nitrogen and optimum levels of phosphorus, potassium, and minor elements and with corn borers originating from 4 geographic areas (Iowa, Missouri, Minnesota, and Ohio). There was a difference in the response of the borer larvae from the 4 regions. The larvae from Ohio seem best adapted to Ohio climate, as indicated by survival and damage inflicted. Larvae from Iowa and Missouri are apparently well adapted for survival but have different responses to the 3 levels of nitrogen. Those from Iowa and Minnesota survived about equally well on 100 ppm and 200 ppm nitrogen, while those from Missouri and Ohio survived about the same on 50 ppm and 100 ppm nitrogen, but did much better on 200 ppm. The survival and damage caused by the Minnesota larvae were lower than those of the other States.

In Mississippi corn silks were collected from field-grown corn and lyophilized. Bound and free amino acids were extracted from the silk powder and analyzed for quality and quantity of amino acids. Equal numbers of free and bound amino acids were found in silks from susceptible and resistant corn.

In corn performance trials consisting largely of commercial hybrids grown at Tifton, Ga., only GCP 2075 and Speight D-14 were more resistant than Dixie 18 to the rice weevil and the corn earworm. Sixty-eight inbreds selected for rice weevil and earworm resistance were test-crossed onto F44 x F6 (resistant), GT112 x L578 (moderately resistant), and 0-509 x 0-1130 (susceptible). In general, this material transmitted dominant resistance for the corn earworm but the 0-509 x 0-1130 crosses had about 25% higher rice weevil damage ratings. Over 98% of the entries were more resistant than the 0-509 x 0-1130 strain. A synthetic of South and Central America corn selections with 107 entries had one selection of Colorado Manfredi x Zapalote Grande with near immunity to the corn earworm but the resistance is apparently a husk characteristic.

At Tifton, Ga., corn earworms were reared in the laboratory on silks and kernels of sweet corn inbreds selected for their suspected influence on larval development. Nearly twice as many larvae died after feeding on silks of M-119 or 380 as died after feeding on those of P-39. Larvae survived on inbred 322 but for the second year the weight of the pupae was significantly lower than that of the pupae taken from other inbreds.

At Tifton, tests have shown that a silk channel diameter of 1 inch or less at the tip of the ear and a husk extension of 2 inches or more beyond the tip of the ear are important factors in earworm resistance. Inbreds which showed definite resistance to corn earworm in 1963 and were recommended to corn breeders for use in double crosses are: Texas 612, 601, 325, 403, 529, 303, 585, 587, 533, and Mississippi Mp 313, E, Mp 335, Mp 464, Mp 468, Mp 462, Mp 480, Mp 426. Other resistant inbreds are: F6, F44, GT11 SC270J, GE72, and AB18. Some indication of a moderate amount of resistance to the pink scavenger caterpillar has been found in some lines of corn.

A rice weevil resistance test was conducted at State College, Miss., in 1963. The natural rice weevil population was supplemented by placing heavily infested ear corn in cages at the rate of 4,400 ears per acre. This method furnished a population sufficient to uniformly infest all plots. There were 54 double crosses and 9 single crosses in the test. Kernel infestations ranged from 2.4% for Pioneer 305 to 55.0% for DeKalb 633, Stull 111Y, Funk G732, Pioneer 8224, and McCurdy M97.

At Brookings, S. Dak., a vertical pull technique, recording pounds of force required to remove a corn plant from the soil was developed and used to evaluate corn plants for resistance to corn rootworm in cooperation with the Crops Research Division. One hundred and sixty-two Corn Belt inbreds, 107 synthetics, 55 plant introductions, 70 Rockefeller Topcrosses and 50 inbreds from the Plant Pathology Department of South Dakota State College were field rated for adult leaf feeding, lodging, and larvae feeding on the roots, using this pull technique. Twenty Corn Belt inbreds were given a superior rating in field performance in the presence of a rootworm infestation. Included in the best lines were SD10, N38A, A251, Mo22, and Oh05. Larval feeding damage to the roots was extensive in most lines indicating an

apparent lack of a high level of antibiosis. Marked differences were noted in standability, conformity of the root system and ability to regenerate roots after feeding damage occurred. Synthetics supplied by the Pioneer Hi-Bred Corn Company were developed from crosses of Corn Belt inbreds with Zapalote, Mexican, and West Indian germ plasm. A high percentage of the Zapalote synthetics had a good score for standability under rootworm infestation. A number of lines exhibited tremendous regenerative capacity. Other lines consistently had some plants with a low score for larval feeding damage and will be investigated further for possible presence of antibiosis. As a group the plant introduction material had a low score for performance under rootworm infestation. The Rockefeller Topcrosses exhibited great vigor and variability and therefore were difficult to evaluate. A number of lines had a low level of larval feeding and will be investigated as possible sources of antibiosis. The Plant Pathology lines obtained from South Dakota State College have been under development for 15-20 years as sources of root rot resistance. Approximately a dozen had superior field performance.

2. Small Grain and Sorghum Insects. Several thousand F_3 to F_6 hybrid selections from the North Dakota breeding program were evaluated and reselected at Minot, N. Dak., on the basis of agronomic qualifications and reaction to sawfly and rust. Selection 60-54 from the cross 51-3549 x II-50-17, a product of the North Dakota program, continues to show promise. It has the desired resistance to sawfly and rust as well as good agronomic qualifications. It was passed by the Crop Quality Council at their January 1964 meeting but will be required to undergo two more years' tests before its suitability for release will finally be determined. In the International Sawfly Nurseries, several varieties and advanced hybrid selections from the breeding programs of Canada, Montana, and North Dakota exhibited a degree of sawfly resistance equal or superior to that of the resistant Rescue check.

Tests were conducted at Stillwater, Okla., to compare yields of greenbug resistant and non-resistant barleys. Replicated plots of greenbug resistant Will and susceptible Rogers barleys were heavily infested with greenbugs during the fall. Duplicate non-infested plots were used for yield comparison. In the infested plots, Will yielded 68.6 bushels per acre compared with 9.8 for Rogers. In the non-infested plots, Will averaged 69.0 bushels per acre while Rogers yielded 72.5.

Fifty-five commercially accepted winter barley lines were evaluated for greenbug resistance at Stillwater. Ten were found to be resistant to both greenbug strains. Of 1295 winter barleys from the World Collection, 85 had a high degree of resistance to the greenhouse strain. The same lines were retested against the field strain and had resistance comparable to resistant Omugi. The newly released variety, Will, is resistant to both greenbug strains.

At Stillwater, greenbug resistant wheat selections and susceptible Ponca were heavily infested with the aphids to evaluate the effect of damage on yield in these two wheats. Duplicate plots remained uninfested for comparison. Stillwater Selection 598660 produced the highest yield (40.9 bu. per acre) under infested conditions, while Ponca yielded 38.9 bu. per acre. In the uninfested plots, 598660 yielded 45.9 bu. per acre as compared to Ponca (46.9).

Approximately 32,000 small grain varieties from the World Collection of Small Grain, advanced breeding material from 10 States, and miscellaneous uniform nurseries were evaluated for resistance to the cereal leaf beetle at Galien, Mich. Sixteen thousand nine hundred and eleven of these were wheat varieties, 1979 of which had no feeding or only a trace; 5,511 were oat varieties, 216 of which showed only a trace; and 8709 were barleys, 25 showing only a trace of feeding. Infestation data indicated that wheats were less preferred than oats and barley for egg oviposition and had less adult and larval feeding damage than oats and barley.

Approximately 18,000 lines, hybrids, varieties, or selections from 6 different States were evaluated for hessian fly resistance at Lafayette, Ind., and Manhattan, Kans. Several of these entries showed a good degree of resistance to the Hessian fly.

At Tifton, Ga., 400 entries from the World Oat Collection were evaluated for possible sources of resistance to aphids and the disease Barley Yellow Dwarf. Twenty-six varieties had low aphid populations and generally appeared to be more free from the symptoms of Barley Yellow Dwarf.

At Tifton 64 out of 199 grain sorghum lines screened showed some resistance to the sorghum midge. Thirty-eight lines were highly susceptible, while 76 were intermediate. Twenty-one lines were discarded due to poor agronomic features. Sorghum midge was first noticed on July 5 in the grain sorghum nursery. Although midge populations were generally high throughout the flowering period, a direct correlation existed between midge abundance and grain damage, even in supposedly resistant lines.

H. Insect Vectors of Diseases

1. Corn Insects. Efforts are continuing to find the vector of corn stunt virus disease in Mississippi and Louisiana. Dalbulus maidis (a known vector of corn stunt) has not been found in the infected area. Only two species of leafhoppers, Draeculacephala portola sp. portola and Graminella nigrifrons, were found on corn in Texas. Twenty-two species of leafhoppers and specimens of Delphacidae and Fulgoroidea were found in grass and weeds adjoining cornfields. The corn flea beetle, Chaetocnema pulicaria was found in all locations. Corn stunt disease occurred with considerable severity over a large area in Mississippi and an area of suspected stunt occurred in Ohio during the summer of 1963. Surveys were made in these areas in July and August and other reports were obtained

indicating possible occurrence in Alabama, Georgia, Indiana, Kentucky, Missouri, and South Carolina.

At Brookings, S. Dak., studies have been completed on pumpkin mosaic virus and its insect vectors, a cooperative project between the Crops Research and Entomology Research Divisions. Symptoms, thermal inactivator, dilution endpoint, longevity in vitro, resistance to freezing, and host range have been determined for the disease. Insect vectors were the beetles Acalymma vittata, Diabrotica sp., and grasshoppers Melanoplus differentialis and M. bivittatus.

In Rehovoth, Israel, (P. L. 480 project A10-ENT-5) it was established that the Delphacid planthopper Delphacodes striatella, an insect species not found in the U. S. A., was the vector of maize rough dwarf virus (MRDV). Efforts are being continued to determine if D. pellucida, which does occur in the U. S., is also a vector. It was also shown that the virus is passed on from a female planthopper to its progeny. This generation to generation transmission of the virus through the egg stage was followed for 12 months and 8 generations, indicating that the reservoir of virus inoculum in nature remains within the vector itself during the winter months when there is no corn growing.

In Helsinki, Finland, (P. L. 480 project E8-ENT-1), it was established that in addition to Delphacodes pellucida, 4 other species of delphacid leafhoppers having the ability to transmit one or another of the virus diseases have been encountered. The virus diseases in question are oat sterile - dwarf virus (OSDV) and wheat streak mosaic virus (WSMV). None of these species of delphacids passes virus from one generation to another through the egg stage. D. sordidula produces an injury which slightly reduces cereal yields. Symptoms of diseases affecting oats are influenced by the age at which oat seedlings are injected with viruses.

2. Small Grain Insects. Barley Yellow Dwarf and its vectors are under investigation at Brookings, S. Dak., in a cooperative effort of the Crops Research and Entomology Research Divisions. Preliminary emphasis has been placed on the reaction of wheat and its vectors under varying environments in the growth chambers, greenhouse, and field; evaluating wheat varieties innoculated with viruliferous vectors in search of sources of resistance or tolerance to BYDV and host range studies. Growth chamber studies indicate that definitive symptoms of BYDV disease are produced at relatively cool temperatures in combination with light intensities and long photoperiods. Earliest detection of symptoms after innoculation and the most rapid development of the syndrome of the disease in many wheat varieties occurred at 65° F under an 18-hour photoperiod at a 2000-2500 foot candle light intensity. In general it was proved possible to detect BYDV infections in wheat in the field in the fall of 1963, and in the greenhouse throughout the winter and early spring. The screening program has revealed one tolerant wheat variety and three individual plants with probable high tolerance levels. Host range studies indicate several pasture grasses currently being recommended for planting are susceptible to BYDV.

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AREA NO. 8. RICE INSECTS

Problem: A number of insects including leafhoppers, the rice stink bug, and rice water weevil, seriously damage rice in the several rice-growing areas of the United States. More information is needed on safe, effective chemical-control methods, and on cultural-control methods, to destroy these pests and reduce the damage they cause. Additional emphasis should be given to new approaches to control rice insects. Rice varieties need to be evaluated for resistance to major rice insects.

USDA AND COOPERATIVE PROGRAMS

The Department's program on rice insects involves entomologists, agronomists, and plant breeders, and plant pathologists engaged in both basic studies and in the application of known principles to the solution of growers' problems. The research is being conducted at Baton Rouge, La., in cooperation with the Louisiana Agricultural Experiment Station. Some of the lines of work have been underway for only a short period of time.

The Federal scientific effort devoted to research in this area totals 2.2 professional man-years. Of this number 0.3 is devoted to basic biology of the leafhoppers, rice stink bug, and rice water weevil; 0.3 to insecticidal control of rice stink bug and rice water weevil; 0.2 to insecticide residue determinations on rice; 0.2 to varietal evaluation of rice for resistance to stink bug, rice water weevil, and vectors of rice diseases; 1.0 to insect vectors of hoja blanca and 0.2 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Research on rice insects by the States is concerned with biology, ecology, and control. Studies are in progress which are designed to determine the economic importance of the various pest species present in growing rice. Efforts are being made to determine the amount of damage caused by different population levels of injurious species. Life history studies are underway which may reveal the vulnerable links in life cycles which can be exploited in control.

Information is being obtained on pest overwintering sites, spring emergence patterns, mating, egg deposition, length of developmental periods, food habits, number of generations per year, movement and dissemination and host relationships.

Biological and chemical control studies are being conducted in the field and laboratory to determine the most efficient and economical method for reducing damage. Rice samples from plots treated with insecticides are subjected to residue analyses.

There are 3.0 man-years dedicated by the States to research on insects affecting rice production.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Ecology, and Nutrition

Another species of the rice water weevil was discovered in Louisiana during the 1963 season. This species, Lissorhoptrus simplex (Say), was present in a rice field in Acadia Parish, La., together with L. oryzophilus. It is believed that some variance in experimental results with rice water weevil in the past might have been due to differences in species involved.

B. Insecticidal and Cultural Control

In field tests on rice stink bug control in southern Louisiana, carbaryl at 1 lb. per acre and malathion at 0.6 lb. were both effective in controlling adults. However, carbaryl had a longer residual action. Malathion did not give effective control after 6 days; carbaryl still provided adequate control 12 days after treatment. Methyl parathion at 0.25 lb. per acre and phosphamidon at 0.25 and 0.125 lb., gave control of rice stink bugs equal to that obtained with malathion at 0.6 lb. per acre.

In field experiments at Crowley, La., seed treatments with coumaphos at 0.125 lb. per 100 lb. of seed and diazinon at 0.5 lb. gave control of rice water weevils equal to that obtained with aldrin. Seed treatments with Isolan at 2 lb. and lindane at 0.5 lb. reduced plant stands. Definite information was obtained that showed some rice water weevils in the Stoneville, Miss., area have developed resistance to aldrin.

In Louisiana Phorate, Di-Syston, Isolan, and Bayer 25141 applied at the rate of 2 lb. per acre just prior to flooding gave better control of the green rice leafhopper, Draeculacephala portola, than did dimetilan and Bidrin at 2 lb. A foliar spray of Bidrin at the rate of 1 lb. per acre gave excellent control of leafhoppers for 1 week but decreased thereafter.

Insecticides were tested in the greenhouse at Baton Rouge for control of the rice delphacid, Sogata orizicola. Seed treatments with technical Bayer 39007 dissolved in acetone at the rate of 1.0 lb. per 100 lb. of seed gave 100% and 63% control at 10 and 25 days after planting. There was no reduction in seed germination even at rates of 2 lb. of Bayer 39007 per 100 lb. of seed. Sprays of Bidrin, carbaryl,and phosphamidon applied at the rate of 1 lb. per acre gave excellent control of insects introduced 1 day after treatment. Diazinon at 0.5 lb., menazon at 1.0 lb., a mixture of DDT+malathion 1 lb. + 0.5 lb., and Bidrin at 0.25 lb. per acre gave less than 20% control 24 hours after treatment. Bidrin at the 1 lb. rate produced 68% mortality 7 days after treatment. Dimethoate, dimetilan, and isolan sprays were phytotoxic.

Insects were caged on individual leaves at intervals after application of granular formulations of Isolan, dimetilan and phorate at the rate of 2 lb. per acre. Isolan was generally distributed throughout the rice plant; both old and young leaves contained sufficient insecticide to produce significant mortality. Phorate appeared to move into the newer growth in greater concentration. The older leaves of plants treated with dimetilan contained more toxicant than young leaves.

Field experiments conducted in El Salvador in cooperation with USAID personnel showed that control of Sogata orizicola with phorate, Di-Syston, and Bidrin increased yields of rice by 99 - 218%. Yield increases were realized on varieties that are susceptible and moderately resistant to hoja blanca virus.

Coincidental applications of the herbicide propanil and carbaryl, Isolan or dimetilan resulted in damage to rice at Crowley, La. Damage was greatest when carbaryl was applied on the same day as propanil. Injury decreased as the interval between applications of the two materials increased. Application of carbaryl following propanil caused less injury than application before DPA was applied. Dieldrin at 0.25 lb. per acre, phorate at 2 lb., Di-Syston at 2 lb., toxaphene at 2 lb., and Bidrin at 1 lb., applied on the same day as propanil did not alter the selectivity of the herbicide.

C. Insecticide Residue Determinations

Studies at Baton Rouge, La., in cooperation with the Fish and Wildlife Unit of the Department of Interior, showed that crayfish reared in rice plots with aldrin and dieldrin residues of 0.20 and 0.80 ppm, respectively, contained residues of 0.4 - 2.7 ppm of dieldrin. In plots planted with treated aldrin seed, residues of 1.6 - 3.9 ppm aldrin were found in crayfish. No reduction in reproduction and growth of crayfish was found in plots planted with aldrin-treated seed and/or sprayed with either carbaryl or methyl parathion.

Rice plants treated with 0.125, 0.25, and 0.50 lb. of Bidrin at Crowley, La., had residues of 1.8, 9.0, and 9.9 ppm 6 hours after application. At 10 days, the residues were 0.26, 1.1, and 0.9 ppm. When the rice was harvested 20 days after treatment, the residues were 0.04, 0.23, and 0.40 ppm. Brown rice, the bran, milled rice, and cooked rice from the 0.25 lb. per acre application had residues of <0.01, 0.07, <0.01, and <0.02 ppm, respectively.

The magnitude and distribution of aldrin and dieldrin residues were investigated in fields in Louisiana planted with rice treated with aldrin for control of rice water weevil and grape colaspis. Soil samples collected from fields prior to sowing contained less than 0.1 ppm of aldrin and 0.2 - 1.1 ppm of dieldrin. Samples taken from the row soon after sowing the treated rice contained 0.4 - 1.5 ppm of aldrin but showed no increase in

dieldrin residue above the samples taken prior to sowing. Samples taken 2-1/2 and 5 inches from the row soon after sowing contained less than 0.1 ppm of aldrin. Samples collected at the end of September showed no aldrin in soil from untreated plots or at locations 2-1/2 and 5 inches from the row in treated plots, but soil from the row in treated plots contained from 0.4 to 0.28 ppm of aldrin. The dieldrin content of soil from the plots sowed with untreated rice averaged 0.33 ppm, while soil from plots with treated rice averaged 0.4 to 0.42 ppm of dieldrin. There was no significant difference in dieldrin residues between locations in the treated plots. Seed planted in Louisiana usually is treated with aldrin (1/4 to 1/2 lb. per 100 lb. of seed) to control the grape colaspis and the rice water weevil. Wild ducks sometimes feed in freshly planted rice fields. In a cooperative study by the Entomology Research Division, the Department of Zoology and Entomology of Louisiana State University, and the Fish and Wildlife Service, U. S. Department of Interior, the oil glands of wild ducks were collected at two locations in Louisiana in April 1963 and at one location in September 1963. These oil glands were analyzed for dieldrin and the amount found ranged from less than 0.003 ppm (limit of sensitivity of analytical method) to 1.14 ppm. The species of ducks, sex, or location where the ducks were collected showed no correlation with the dieldrin content of the oil glands.

D. Insect Vectors of Disease

An efficient transmitter of hoja blanca is now available for experimental use at Baton Rouge, La. Transmission of hoja blanca virus was effected with most of the progeny from some transmitter X transmitter matings of Sogata orizicola, vector of hoja blanca disease. Only 3 of 14 matings had fewer than 85% of the progeny transmitting the virus. Transmission for the progeny from the remaining 11 matings averaged 96.5%. Active vectors 1-5 days old and those 15-20 days old, transmit hoja blanca virus with equal frequency. Females are more efficient vectors than males.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Basic Biology, Ecology, and Nutrition

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Lamey, H. A., McMillian, W. W., and Hendrick, R. D. 1964. Host ranges of the hoja blanca virus and its insect vector. Phytopathology 54:536-541.

Insecticidal Control

Everett, Travis R. 1964. Insecticidal seed treatments for control of rice water weevils. 55th Annual Progress Report of the Rice Experiment Station. pp. 168-170.

Everett, Travis R. and Showers, W. B. 1964. Effects of insecticide and fungicide treatments on germination of rice seeds. 55th Annual Progress Report of the Rice Experiment Station. pp. 177-178.

Hendrick, Rodney and Everett, Travis R. 1964. Resistance to aldrin insecticide in the rice water weevil. 55th Annual Progress Report of the Rice Experiment Station. pp. 173-177.

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AREA NO. 9. COTTON INSECTS

Problem. Insects are major deterrents to economical production of cotton and their control is a major cost factor in the production of the crop. Although many highly effective insecticides have been made available, the development of resistance to certain insecticides in 20 cotton insect pests emphasizes the need for basic information on ways to solve or avoid the problem and to develop other methods of control that are more effective, economical and desirable. There are some hazards involved in the use of current insecticides because of possible resulting residues in food and feed products made from cottonseed and because of drift to vegetable and fruit crops, and to forage crops consumed by animals. An imbalance of beneficial insect populations and hazards to fish and wildlife may result from insecticides now employed on cotton. More research on approaches to control such as sterile male techniques, attractants, feeding stimulants, repellents, cotton varieties resistant to insects, biological control agents, safer insecticides, more effective ways of applying them, and chemically induced plant resistance to insect attack is needed to develop improved methods of control. Effective methods of eliminating the pink bollworm and boll weevil from newly infested areas and possibly eradicating them from all areas are needed. The boll weevil is gradually extending its range westward and may be adapting itself to an arid climate. Infestations in northern Sonora, Mexico, could endanger cotton production in California where the pest does not now occur. One of the basic difficulties in cotton insect control is the lack of knowledge of factors influencing insect abundance. Such knowledge could serve as a basis for advising growers when control measures for the various pests will or will not be required.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long term program involving entomologists, insect and plant physiologists, insect pathologists, insect and plant geneticists, chemists, biochemists, agricultural engineers, soil scientists, and economists engaged in basic studies and the application of known principles to the solution of cotton growers' insect problems. Studies of ecological factors affecting abundance and distribution of cotton insects are conducted at Tucson, Ariz., Tallulah, La., State College and Stoneville, Miss., Florence, S. C., and Brownsville and Waco, Tex., in cooperation with the Agricultural Experiment Stations in the respective States and with ARS Plant Pest Control Division. Fundamental research in determining physiological processes and biochemical requirements in the normal metabolism of the boll weevil, bollworm, pink bollworm and cabbage looper is conducted at Baton Rouge, La., State College, Miss., Florence, S. C., College Station and Brownsville, Tex., in cooperation with the Agricultural Experiment Stations in the respective States. Studies of mode of action and fate of various chemicals in the insect, mechanisms by which insects develop resistance to

insecticides, and how such mechanisms may be rendered ineffective are conducted at Baton Rouge, La. in cooperation with the Louisiana Agricultural Experiment Station. Evaluations of candidate chemicals for cotton insect control in the laboratory and field are conducted at Tucson and Tempe, Ariz., Tallulah, La., State College and Stoneville, Miss., Florence, S. C., and Brownsville, College Station, and Waco, Tex., in cooperation with the respective Agricultural Experiment Stations and Industry. Development of safe, economical and effective schedules of insecticide applications for guidance of growers in meeting the wide variety of insect problems on cotton is underway at Tempe, Ariz., Tallulah, La., Stoneville, Miss., Florence, S. C., and Brownsville and Waco, Tex., in cooperation with the respective Agricultural Experiment Stations. Studies involving insect pathogens for control of the boll weevil, bollworm, tobacco budworm, and cabbage looper, and beneficial insects for the control of several cotton insects, are conducted at Brownsville and Waco, Tex., Tucson, Ariz., State College and Stoneville, Miss. and Florence, S. C. in cooperation with the Agricultural Experiment Stations in these States. Research to discover new approaches to control cotton insects such as sterile male techniques, attractants, feeding stimulants, and repellents are conducted at Tallulah, La., State College and Stoneville, Miss., Florence, S. C., Brownsville, and College Station, Tex., in cooperation with the Agricultural Experiment Stations in these States. Studies to evaluate equipment for insect control and detection such as stalk shredders, machines to collect and destroy boll weevil infested cotton squares, gin and oil mill equipment, and light traps, are conducted at State College and Stoneville, Miss., and Brownsville and Waco, Tex., in cooperation with the Agricultural Experiment Stations in these States and with the Agricultural Engineering Research and Plant Pest Control Divisions. Varietal evaluation for insect resistance is studied at Tucson, Ariz., State College, Miss., and Brownsville, Tex. in cooperation with the Agricultural Experiment Stations in these States and the Crop Research Division.

The Federal scientific effort devoted to cotton insects research totals 64 professional man years. Of this number 22.1 are devoted to basic biology, physiology and nutrition; 17 to insecticidal and cultural control; 5.2 to biological control; 11.7 to insect sterility, attractants and other new approaches to control; 1.3 to evaluation of equipment for detection and control; 3.7 to varietal evaluation for insect resistance; and 3 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Extensive research programs on cotton insects are conducted by the major cotton-producing States. Information is being obtained on the ecological factors responsible for rapid population increases of pest insects as a basis for accurate forecasting of destructive outbreaks. Variations in insect numbers and behavior through hibernation, spring emergence, summer development and diapause are being determined. Laboratory studies are underway to learn what factors are responsible for initiation of diapause

in the boll weevil, pink bollworm and bollworm. Emphasis is being placed on the influence of light, nutrition and temperature. Other studies are concerned with the influence of chemosterilants and radiation on reproductive physiology. Laboratory rearing techniques, using artificial lights, are being developed to provide insects for year-round study, and to determine the effects of varying concentrations of nutrients in the diet.

Biological information is being assembled on rates and characterization of developmental stages, rate of egg deposition, mating habits, longevity and mortality.

Cultural control studies include the influence of varying fertilizer levels on infestation size, the benefits obtained from crop residue destruction in the fall, and the development of varietal resistance. Research in the last area consists of screening introduced plants for resistance, crossing them and selecting progeny which exhibit useful traits. Biological, physiological and chemical studies are conducted to determine the factors responsible for resistance.

Chemical control studies include the evaluation of new materials with particular emphasis on systemic insecticides. Research includes basic mode of action studies in insects and the metabolism of systemic insecticides in the cotton plant. Various methods of application are being evaluated for field use.

The total State scientific effort devoted to cotton insect research is 21.5 man-years.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition.

1. Boll Weevil. Heavy boll weevil infestations were present in cultivated cotton in Sonora, Mexico, in the summer of 1963. In a field near Oquitoa 46% of the squares were punctured on July 25. The infestation had increased to 77% on August 29 even though the field had been treated twice with Guthion. Forty percent of the squares were punctured in a field near Magdelena on August 27 and 37% in a field near La Salina on September 13. Percentages of squares infested in cotton fields near Caborca, Desemboque, and La Salina, were 100, 79, and 90, respectively, on October 17 and 18. Similar infestations were found in the area last year.

First thurberia weevil punctured squares were found on cultivated cotton in southwestern Arizona on August 21 in 1963. Nine thousand three hundred squares were inspected in 16 fields in the upper Santa Cruz Valley. Punctured squares were found in 14 fields but only about one percent of the squares were punctured.During November light to moderately heavy infestations of boll weevils were observed in eastern Yuma, southeastern Pinal, and

various parts of Pima Counties. The heaviest infestation was located about 5 miles south of Stanfield in Pinal County.

Boll weevil survival in the spring of 1964 was higher than in 1963 in all areas except Texas and 3 areas of the Carolinas. Spring woods-trash examinations for hibernating boll weevils were made in central Texas, northeast Louisiana, Delta and Hill sections of Mississippi, and in four areas in the Carolinas. Comparative survival since 1960 in the various areas was as follows:

	Weevils per acre				
Area	1960	1961	1962	1963	1964
Central Texas	2065	1516	1361	452	97
Northeast Louisiana	4754	2193	2233	121	1049
Mississippi	821	1246	1132	13	289
South Central, S. C.	861	376	1667	914	753
Coastal Plains S. C. & N. C.	1049	1129	3654	1560	2742
Piedmont S. C. & N. C.	590	1558	2833	350	134
North Central, N. C.	377	430	968	161	107

Survival was lower in all areas of the Carolinas except in the Coastal Plains. Survival was lower in central Texas than in any year since such records have been made. Although survival in Louisiana and Mississippi was greater than in 1963, it was considerably lower than in previous years.

The ground trash survey by Tucson, Ariz. laboratory personnel in April 1964 in Sonora, Mexico, showed averages of 138 and 360 boll weevils per acre in treated and untreated fields, respectively. Treated fields received 3 biweekly airplane applications of methyl parathion beginning in early October, 1963.

No weevils were found overwintering in ground trash in Arizona by Tucson laboratory personnel. Ground trash inspections from 17 fields in Pima, Pinal, Santa Cruz and Yuma Counties made in February, and April, 1964, indicated that the thurberia weevil in Arizona had not been able to adapt itself to survive the winter in ground trash. Field-collected adults placed in hibernation cages containing ground trash at two locations where infestations occurred last year, also, failed to survive.

Overwintering boll weevils at a rate of 1100 per acre were found in last year's cotton bolls on April 13 in a Pinal County stub cotton field by Tucson, Arizona, laboratory personnel. In such fields the plants are cut at ground level and the new crop is produced from the previous year's root stocks. Adult weevils were recovered from terminal growth on stub cotton as early as April 21. Fourteen weevils were collected on April 15 from a hibernation cage containing 200 bolls from the same field.

The boll weevil infestation in squares increased ten-fold between June 1 and 22 in an Arizona stub cotton field. Tucson laboratory personnel found 50 weevil-punctured squares per acre on June 1, 640 on June 15, and 5,009 on June 22, in a stub cotton field in Pinal County. Second generation adults were emerging by June 11.

In laboratory studies at Tucson when the F_1 generation resulting from crossing weevils from wild cotton, Gossypium thurberi, with weevils from domestic cotton was back crossed to the parental lines, progeny from all crosses reproduced, indicating that the weevils are of the same species.

Preliminary results at State College, Miss. indicate development of an easy method of marking large numbers of boll weevils for field studies. Yellow model lacquer, diluted 1:1 with acetone, was applied to boll weevil adults with an atomizer. At the end of three weeks the markings were very conspicuous and mortality was insignificant.

Three additional species of Cienfuegosia and one of Thespesia were hosts of the boll weevil at Brownsville, Tex. Susceptibility of Cienfuegosia differed among six species grown in the nursery, three of which were previously reported hosts. In general, the species not found in areas inhabited by the boll weevil were the least susceptible.

In studies at Baton Rouge, La. aseptically and non-aseptically reared adult boll weevils were equally capable of synthesizing long-chain fatty acids from acetate. Palmitic, palmitoleic, stearic, oleic, and linolenic acids were the principal ones synthesized. The studies further indicated that the boll weevil cannot synthesize linoleic acid from acetate, and cannot convert dietary linolenic acid to linoleic acid.

Gas chromatography of isolated sterol esters of diapausing adult boll weevils at Baton Rouge, La. revealed that oleic acid is the principal acid esterified with sterols. Paper chromatography of the esters indicated that they were at least 97% pure and were not contaminated with glycerides or glyceride fatty acids. The sterol ester fraction also gave a very strong positive test for sterol.

In studies at Baton Rouge, La. the sugar content of cotton bolls was five to eight times greater than in squares. This differential probably explains why glycogen and triglyceride levels are higher in boll-fed than in square-fed weevils. Preliminary results indicate that the major sugars in bolls and squares are glucose, fructose, and perhaps sucrose.

Triglyceride need in the diet for normal development and reproduction in the boll weevil was determined at Baton Rouge, La. Larvae of normal appearance and size were obtained from essentially fat-free diets. The only deficiency symptom was a slightly retarded growth rate. Progeny from parents reared and fed with fat-deficient diets developed normally on fat-deficient larval diet. Resistant and non-resistant strains of weevils developed equally well on diets without fat. Surprisingly, weevils from the two strains required

just as much endrin to produce a given mortality as when reared from diets with the usual amount of fat.

In studies at College Station, Tex., sublethal dosages of systemic insecticides reduced egg production of boll weevils. Adult boll weevils maintained under constant systemic insecticide pressure by being fed the toxicant or by allowing the weevils to walk on treated filter paper, produced few or no eggs. Feeding was much more effective in reducing egg production than the residue treatment. One ppm of phorate, Bidrin, American Cyanamid 47470 or 47031 in artificial diets almost stopped egg production.

Use of C^{14}-labeled acetate in studies at Baton Rouge, La. indicated that the boll weevil has an active mechanism for the biosynthesis of lipids. Radioactivity from injected C^{14} appeared in neutral lipids and phospholipids. The weevil incorporated 2.8% of the labeled acetate into the lipid fraction within 2 hours of injection. About 1.8% was recovered as $C^{14}O_2$ from respiratory oxidation of the acetate molecule. Fatty acids appeared to be the principal compounds synthesized by boll weevils from the C^{14} acetate precursor. Approximately 90% of the recovered radioactivity was in the saponifiable fraction. Ten percent was not saponifiable. A small portion (about 17%) of the non-saponifiable fraction was precipitated by digitonin, indicating the possibility of sterol biosynthesis in this insect.

Boll weevils reared on high cholesterol diets at Baton Rouge, La. tolerated about 1.5 times more methyl parathion than those reared on diets containing the usual amounts of sterols. Tolerance levels were not increased when the weevils were reared on diets containing increased amounts of selected amino acids, triglycerides, or a mixture of cholesterol and cholestanol. The purpose of the test was to determine whether it would be feasible to increase the tolerance of sterilized insects to insecticides by nutritional means before their release in the field.

Radiotracer studies at Baton Rouge, La. showed that almost all of the cholesterol in newly emerged adult boll weevils was replaced within 15 days. This high rate of sterol turnover had been indicated by earlier nutritional studies. Significant amounts of C^{14}-cholesterol were esterified and smaller amounts were converted to more polar steroids. Fat weevils contained more sterol esters than lean weevils. The polar steroid fraction recovered from adult feces was separated into several components by means of thin layer chromatography.

Catalytic hydrogenation of crude body fat of the boll weevil at Baton Rouge confirmed earlier identifications of the unsaturated fatty acids, and revealed traces of two additional minor components. Gas chromatography of hydrogenated fat showed a trace of C_{19} fatty acid that was obscured by the large polyunsaturated C_{18} peaks. Also, a small peak in the C_{17} area which disappeared after hydrogenation is probably palmitolenic acid. It represents less than 1% of the crude mixture.

In studies at Baton Rouge the hydrocarbon and sterol ester fractions of boll weevil lipids were isolated by thin layer chromatography using two different solvent systems in series. A preliminary development in petroleum ether moves the hydrocarbon fraction almost with the solvent front and leaves the sterol esters near the origin. A second development in petroleum ether, ethyl ether and acetic acid (84:15:1; v/v/v) to a point 3 cm below the first front and then resolves the sterol esters. Three distinct sterol ester spots have been isolated from crude body fat by this method.

The composition of purified boll weevil larval glycogen was determined in studies at Baton Rouge, La. The glycogen is 66.3±0.8% carbohydrate positive material, 5.8±0.5% protein, 10.4±0.5% moisture, and 7.7% ash. Chromatography on Sephadex G-200 and high voltage paper electrophoresis did not show any carbohydrate contaminant.

A method was developed at Florence, S. C., for accurate sex determination of boll weevils. Weevils are anesthetized with CO_2. Each specimen is held between the index finger and thumb with the posterio-ventral portion of the insect facing the observer so that the morphology of the last tergum and sternum is exposed. The weevil is illuminated with a bright light and viewed through a stereoscopic microscope with a magnification of approximately 25 diameters. The seventh tergum of the female is wider (1.1 mm.) than long (0.5 mm.) and fits smoothly against the edge of the last sternum. The eight tergum of the male is narrower (0.5 mm.) and shorter (0.3 mm.) than the seventh tergum of the female. The distinguishing characteristic of the male is a notch in the ventral portion of the eighth tergum.

In studies at Florence, S. C., the boll weevil was most sensitive to light in the 500 to 510 mu region (green) of the spectrum. Electroretinograms of the compound eye of laboratory-reared weevils indicated that the greatest sensitivity occurs in the 500 to 510 mu region of the spectrum. Cotton foliage reflects light in this range.

Studies of the systemic activity of Shell SD-9129 in the cotton plant and its metabolism in insects, rats and the cotton plant at College Station, Tex., showed that SD-9129 is not translocated when applied as a foliar treatment but is readily translocated when applied as a stem treatment. It undergoes oxidation in insects and rats similar to the closely related compound, Bidrin. In all animal species studied, hydrolytic degradation apparently occurred only at the methyl-phosphate and vinyl-phosphate bonds of the molecule. No amidase action was detected.

Radioassay and biological assays were used in systemic activity studies of Di-Syston at College Station, Tex. Di-Syston applied 12 inches under the soil surface was absorbed more readily by plants 18 inches tall than when it was placed 6 inches deep. The ability of the plant to take up the toxicant depended on the dispersal of the toxicant in the soil. The application of Di-Syston to cotton stems was not very effective. P^{32}-labeled material was used in studies of metabolism of Di-Syston in cotton insects and

the cotton plant. A total of five oxidative and ten hydrolytic metabolites were found.

The substitution of sucrose for glucose improved the amino acid diet for boll weevils in nutrition studies at College Station, Tex. Substituting 3.5 g. of sucrose for 2.5 g. of glucose and increasing glutamic acid from 125 mg. to 325 mg. per 100 g. of diet improved the boll weevil amino acid diet. Several other sugars were tested. Sucrose, fructose, and maltose gave the best results. Lactose, corn starch, cellibiose, glucose, and mannose were intermediate and galactose, melibiose, and ribose gave poor results.

The percentage of fatty acid fractions varied with boll weevils' susceptibility to various insecticides in studies at Florence, S. C. The percentage of stearic acid was higher and the percentage of palmitic and oleic acids was lower in insecticide-susceptible boll weevils than in those resistant to the insecticides. Three strains of weevils reared on different artificial diets and field-collected weevils were treated with Guthion, carbaryl, toxaphene, and toxaphene plus DDT. The survivors and dead from all treatments showed this difference in fatty acid content.

In studies at Florence, S. C. three strains of laboratory-reared weevils were most susceptible to toxaphene when fed a diet containing soybean lecithin and least susceptible when fed cotton squares. Weevils surviving treatment with Guthion, carbaryl and toxaphene plus DDT were generally heavier and contained a higher percentage of lipid than the dead ones.

Length of photoperiod that will initiate diapause in the boll weevil has been determined in studies at Baton Rouge, La. Periods of fluorescent illumination less than 11 hours and 40 minutes tended to enhance diapause induction. Longer photoperiods suppressed diapause. This information will be useful in future studies of the photoperiodic action of light of different wavelengths.

In studies at Stoneville, Miss., boll weevil adults required 2 to 3 weeks to attain firm diapause under controlled environmental conditions in the laboratory. When larvae were reared on artificial diets, squares, or bolls under an 11-hour photoperiod at 80° F., and when adults were fed on squares or bolls under continuous light at 80° F. In other experiments larvae were reared on squares, bolls, or artificial diets under continuous light at 80° F. Adults from these larvae fed on squares and bolls under continuous light at 80° F., or held under a 12-hour photoperiod at 80° F. in the day and 50° F. at night fed squares or bolls required a similar period to attain firm diapause.

In nutrition studies at Baton Rouge, La. cholestanol did not satisfy the sterol requirements for boll weevil development but it reduced the need for cholesterol in the diet. Larvae did not develop normally when reared on diets containing less than 20 mg. of cholesterol per 100 g. of diet. However, they were able to develop satisfactorily on diets containing only 10 mg. of

cholesterol supplemented with 10 mg. of cholestanol. Larvae did not survive on diets containing 100 mg. of cholestanol alone.

C^{14}-labeled fatty acids from the boll weevil were separated and identified by gas chromatography at Baton Rouge, La. Radioassay of the separated esters was accomplished by collecting them on silicone-coated anthracene crystals in glass cartridges. The cartridges were then counted for C^{14} in a scintillation spectrometer.

Effects of several amino acid analogs on boll weevil development were studied at College Station, Tex. DL-Methionine and allylglycine appeared to be detrimental to its development.

Sub-lethal treatment of boll weevils with toxaphene increased egg production in tests at State College, Miss. Female weevils that survived treatments with toxaphene laid more eggs than untreated females. However, approximately 50% of the treated females died by the fourth day after treatment.

The metabolism of Di-Syston by adult boll weevils and bollworm larvae was compared in studies at College Station, Tex. Fifth-instar bollworm larvae absorbed and excreted the toxicant very rapidly following topical treatment. After 72 hours, 78% of the applied dose was excreted. Adult boll weevils also absorbed and excreted Di-Syston quite rapidly. Bollworm larvae rapidly oxidized and then hydrolyzed injected Di-Syston. Ingested Di-Syston was oxidized to a lesser extent but was rapidly hydrolyzed in the gut. The metabolism of Di-Syston by adult boll weevils was similar to that of bollworms except that no Di-Syston sulfone was recovered from the weevils.

In studies at Baton Rouge, La. boll weevils reared on larval diets containing a minimum amount of sterol and deprived of any sterol during the adult stage, laid practically no eggs and survived only a short time. The mean life span for adult weevils on diets essentially free of sterols was 14 days as compared with 55 to 89 days for square-fed weevils. It made little difference whether the weevils were or were not mated. Such a dependence on dietary sterols has not been observed in any other insect. The addition of cholestanol to cholesterol-free adult diets increased egg production and prolonged the life span probably by supplementing or sparing the cholesterol carried over from the immature stages.

Glycogen levels through the life cycle of the boll weevil were determined in studies at Baton Rouge, La. Eggs contained the largest quantity of glycogen (about 11% of the dry weight) and the late last instar larvae were second (about 6%). During the pupal period, glycogen content gradually decreased and reached a minimum in the one day old adult. Diet has a profound influence on the rate of glycogen accumulation. Glycogen increased slowly in the square fed weevil and reached a peak at the fifteenth day. When the weevils were fed bolls, however, glycogen content increased very rapidly--from about two micrograms in the one-day old adult to about 70 micrograms in the two day old weevil. This sudden increase was probably caused by a high titer of glucose in the boll.

Chemoreceptor and mechanoreceptor sense cell response was recorded from the boll weevil in electrophysiological studies at Florence, S. C. In preliminary electrophysiological technique studies of the boll weevil, satisfactory mechanoreceptor recordings have been made from the antenna and chemoreceptor recordings from the sensilla basiconica on the maxillary palps.

In studies at State College, Miss. clear, mitotic metaphase figures have been observed in the thurberia weevil and the chromosome number has been established to be 44 as in the boll weevil. However, small differences between thurberia and boll weevil chromosome configuration have been observed.

2. Pink bollworm. A low mating frequency of pink bollworms was indicated in early-season populations in studies at Brownsville, Tex. Laboratory studies showed that each spermatophore represents one mating. Dissections of females collected in light traps over a 2-year period showed a high percentage to be unmated early in the season and during the noncotton season when the population density was low. As the population increased with advance of the growing season, the proportion of mated individuals showed a significant correlation to numbers trapped in the respective trapping periods, as did the mean number of matings per female. Of the total trapped during the study a majority mated only once. Laboratory studies of caged populations showed that females have the potential to mate an average of 4.3 times (range, 0-10) and males 2.3 times (range, 0-8). Among these caged populations, 5% of the males and 3% of the females failed to mate, and 10% of the once mated females contained no spermatophores when dissected.

Winter survival of pink bollworms was reduced by low temperature and high soil moisture in bio-climatic cabinet studies at Brownsville, Tex. A cabinet simulating winter temperatures at Heavener, Okla., resulted in a survival 1/10 of that in a cabinet simulating the higher winter temperature at Waco, Tex. Under Waco temperatures a soil moisture of 16% significantly reduced survival from that obtained at a soil moisture of 8%. No difference in survival due to soil moisture was found under the lower temperatures at Heavener, Okla.

3. Other Cotton Insects. Surveys by Brownsville, Tex. personnel of cultivated hosts in the lower Rio Grande Valley of Texas during July, August and September showed that an increasing proportion of the larvae was Heliothis virescens. This species was not found on corn or grain sorghum. Attractive cultivated hosts during late August and early September were scarce. During this time a few H. zea were found on Passiflora suberosa. H. virescens was more abundant on this plant than H. zea and was also found in small numbers on sunflower.

Heliothis zea larvae in corn ears completed development after killing frost at Brownsville, Tex. Collection of bollworm larvae for experimental

purposes was interrupted by temperatures of 32° and 27° F on December 23 and 24, 1963. High populations of H. zea were observed in corn ears after these low temperatures. The larval mortality appeared to be low and collections after the freeze showed that a high percentage of this December-January brood completed development.

The effects of several amino acid analogs on bollworm development were studied at College Station, Tex. DL-Methionine and allylglycine appeared to be detrimental to its development.

Lygus bug injury did not appear to cause "flat square" problem on cotton in studies at Tucson, Ariz. Some individual cotton seedlings exposed to as many as five lygus bugs grew into deformed and somewhat stunted plants which produced fewer squares and blooms than did plants not injured by lygus feeding, but no flat squares resulted indicating that lygus bugs probably are not responsible for the flat squares produced by cotton plants in Arizona fields.

Tarnished plant bugs reduced cotton yields in cages at Stoneville, Miss. Studies of different adult populations released in replicated large screen cages indicated that adults migrating into cotton fields at a weekly rate of 1 to every 5 cotton plants can significantly reduce cotton yields.

Spanogonicus albofasciatus overwinters in egg stage on fall and winter weed hosts at Tucson, Ariz. In laboratory studies where green winter host material was brought into the laboratory and held long enough for incubation, S. albofasciatus nymphs hatched from Sisymbrium irie, Malva parviflora and Erodium cicutarium.

B. Insecticidal Control.

1. Boll Weevil. Six applications of 0.5 pound of methyl parathion per acre, plus defoliation, followed by 1.0 pound of Bidrin was the most effective boll weevil diapause control program tested at State College, Miss. The above combination of treatment procedures was highly effective in reducing boll weevil numbers during September and October. Good results also were obtained when 2.0 pounds of Bayer 41831 per acre was substituted for Bidrin in a similar program. The fields were replanted to cotton in 1964. On June 9 no weevils were found in two fields which had been defoliated or treated with Bidrin following methyl parathion treatment in the previous fall. However, weevils at the rate of 26 per acre were found in the field treated with Bayer 41831 after the methyl parathion treatments had been made.

Different volumes of spray in airplane applications of insecticides were equally effective in controlling cotton insects at Tallulah, La. Airplane applications of the same dosage of toxaphene plus DDT were made throughout the season in 1, 2, and 3 gallons of total liquid per acre application in comparison with Hi-Boy applications of 4 to 6 gallons per acre. There was no difference in insect control, fruiting of the cotton plant, or yield for the different volume rates of spray applied.

In field tests at Stoneville, Miss. under moderate to heavy late-season boll weevil infestations a mixture of Guthion plus Ethyl Guthion at 0.5 and 0.75 pound was as good or better than Guthion plus DDT at 0.25 plus 1.0 pound per acre. Under light to moderate boll weevil infestations Union Carbide 21149 at 0.25 pound, Stauffer N-2404 at 0.5 pound, American Cyanamid CL-47470 at 0.5 pound, and Guthion plus Ethyl Guthion at 0.25 pound per acre held the infestation below that of the check and were equal to or better than the standard.

In field cage tests at College Station, Tex., American Cyanamid compounds CL-47031, CL-47470, and E.I. 47772 applied as sprays at 0.25 pound per acre were as effective against boll weevils and spider mites as the same dosage of Guthion plus Ethyl Guthion.

In field cage tests against adult boll weevils at Waco, Tex., Imidan at 0.5 pound, Bayer 41831 at 1.0 pound, Guthion at 0.125 pound plus Ethyl Guthion at 0.125 pound, and Guthion at 0.25 pound per acre gave kills of 100%; Bayer 25141 at 0.5 pound, 95%; Monsanto CP-40294 at 0.5 pound, 90%; and Bidrin at 0.25 pound per acre, 89%.

In greenhouse tests at College Station, Tex., the boll weevil feeding stimulant used in conjunction with systemic insecticides apparently increased foliar feeding by adults enough to increase rate of kill about threefold over plants treated with only the insecticide.

2. Pink Bollworm. Twenty two candidate insecticides were tested for toxicity to pink bollworm adults in laboratory and field cage tests at Brownsville, Tex. Six were highly toxic to adults in the initial laboratory screening tests and two, Shell SD-8972 and SD-90201, retained appreciable toxicity after a 24-hour outdoor exposure of the spray residues. None was very promising in field cage tests. Populations were too low for the evaluation of insecticides against this pest under field conditions.

3. Other Insects. In field experiments at Waco, Tex., Shell SD-8447 at 1.0 pound and SD-7438 at 1.5 pound per acre gave bollworm control equal to that obtained with toxaphene at 2 pounds plus DDT at 1 pound

per acre. Shell SD-7438 and SD-8448, each at 1 pound per acre, were less effective. There was no significant difference in bollworm control obtained with 1.4 pounds dosages of DDT or TDE or in mixtures with toxaphene at 2.5 pounds plus DDT or TDE at 1.25 pound per acre.

In laboratory tests at Tucson, Ariz., Bayer 42696 and American Cyanamid 47548 at 2 pounds, and American Cyanamid 48938 and E.I. 38906 and Bayer 41831 at 1 pound per acre were effective against bollworms.

Stem treatment with systemic insecticides continued to show promise in tests at College Station, Tex. Preliminary tests with Bidrin, Shell SD-9129, and American Cyanamid CL 47031 as stem treatments showed that all of these materials were toxic to third-instar bollworms caged on leaves of treated plants. American Cyanamid CL 47031 continued to be the most effective stem treatment material for boll weevil control.

In small field cage tests at Florence, S. C., General Chemical GC-4702 at 1.5 pounds, carbaryl at 1.2 to 2 pounds, TDE at 2 pounds, DDT at 2 pounds, toxaphene plus DDT at 2 pounds plus 1 pound, and methyl parathion at 1 pound per acre, were effective against the bollworm.

In laboratory tests at Tucson, Ariz., Bayer compounds 41831, 37289, 38156, and 25141 were effective against beet armyworms at 0.5 pound per acre. American Cyanamid E.I. 38906, CL-47470 and E.I. 47772 and Bayer 37289 and 38156 were effective against cabbage loopers at 1 pound per acre. All of the above compounds were effective against the cotton leaf perforator at 0.5 pound per acre. American Cyanamid E.I. 38906, Bayer 41831 and 38156, Niagara N-9227, Geigy G-13005, Stauffer N-4446, R-5762 and R-5763 at 1 pound and Bayer 37289 and Shell SD-9129 at 0.5 pound per acre, were effective against salt-marsh caterpillars. All Bayer compounds and American Cyanamid compounds were effective against adult lygus bugs at 0.5 pound per acre. Shell SD-9129 was effective at 0.25 pound. At Waco, Tex., CL-47031 applied to cotton stems at 0.19 pound per acre and as side-dress granule application at 1.3 and 2.06 pounds per acre gave good reductions of a light cotton fleahopper infestation. In field tests, Union Carbide UC-21149 granules applied in the furrow at planting gave cotton fleahopper control for 7 weeks after cotton was planted. The first significant hatch of nymphs occurred between the 7th and 8th week after planting while in a similar phorate treatment at 1.2 pound, the hatch occurred between the 5th and 6th week. In the untreated check and in the phorate seed treatment at 0.2 pound it occurred one week earlier than in the latter treatments. On June 11, approximately 8 weeks after planting, the nymphal infestation was 16 per 100 terminal

buds in the UC-21149 treatment, 58 in the phorate seed treatment, 66 in the phorate granular treatment, and 83 in the check. There were significantly more squares and blooms on plants in the UC-21149 treatment than in all other treatments, reflecting superior cotton fleahopper control.

At Waco, Tex., in field tests Union Carbide UC-21149 granules applied in the seed furrow at planting at 1.0 pound per acre gave thrips control equal to that of a similar treatment with phorate at 1.2 pounds per acre. Bidrin, American Cyanamid compounds CL-47470 and CL-47031 each at 0.1 pound per acre, phosphamidon at 0.2 pound, Mobil Chemical MC-A-600 at 1.0 pound, and toxaphene at 1.0 pound plus DDT at 0.5 pound per acre, gave good thrips control with no difference among treatments. At Stoneville, Miss., UC-21149 and Dow's Nellite applied as granules in the seed furrow at planting at 1 pound per acre gave good control of light to medium thrips infestations. General Chemical compounds GC-9160 and GC-3707, and Mobil Chemical MC-A-600 at 0.5 pound, Shell SD-9129 at 0.25 pound, and American Cyanamid compounds CL-47031 and CL-47470 at 0.1 pound per acre, gave good control of light thrips populations.

In field experiments at Waco, Tex., Bidrin at 0.1 and 0.2 pound, Geigy G-13005 at 0.25 pound, and Mobil Chemical MC-A-600 at 1.0 pound per acre gave cotton fleahopper control equal to that obtained with 1.5 pound of toxaphene plus 0.75 pound of DDT. American Cyanamid compounds CL-47031 and CL-47470 each at 0.1 pound, phosphamidon at 0.2 pound, and trichlorfon at 0.5 pound per acre were less effective.

In comparative studies at College Station, Tex., with P^{32}-labeled Bidrin and Di-Syston, Bidrin had more systemic activity from soil and stem treatment than Di-Syston. However, studies of the metabolism in soil indicated that Bidrin is detoxified more rapidly than Di-Syston. Aphid bioassay and radioassay studies indicated that Bidrin is taken up much more efficiently by cotton plants by stem treatment than by soil injection. Also, a lanolin formulation applied to cotton stems appeared to release the Bidrin slowly enough so that new growth was toxic to aphids.

In a survey by Stoneville, Miss., laboratory personnel, a resistant population of the spider mite, Tetranychus telarius, was found at Minter City, Miss. The resistant mites were found on a plantation which has had a chronic mite problem. Several recommended miticides such as demeton, chlorobenzilate and Kelthane failed to give satisfactory control. In one test phorate spray at 0.5 pound and 10% phorate granules at 20 pounds per acre gave good reductions of the resistant population.

In small field tests at Florence, S. C., Guthion plus Ethyl Guthion at 0.5 pound, Meta-systox at 0.375 pound, Ethion at 0.5 pound, carbophenothion at 0.5 pound, and demeton at 0.375 pound, gave satisfactory control of the carmine mite, Tetranychus cinnabarinus.

At Waco, Tex., the following materials gave good control of the desert spider mite (Tetranychus desertorum), 1, 3, 7 and 15 days after treatment; Parathion at 0.25 pound; Imidan, at 0.25 pound; Guthion at 0.25 pound; Guthion plus Ethyl Guthion at 0.125 plus 0.125 pound; Bidrin at 0.1 and 0.2 pound; Niagara Nia-9203 at 0.25 pound; and Shell SD-7438 at 0.5 pound per acre.

In tests at Tucson, Ariz., American Cyanamid CL-47031 applied to cotton stems in a lanolin paste at the rate of 5 mg. per plant gave 72-hour mortalities of 77, 92 and 78% when adult lygus bugs were placed on the plants 2, 7, and 14 days after treatment.

C. Biological Control.

1. Boll Weevil. Disease in boll weevils caused by Mattesia sp. was introduced into populations in field cages at State College, Miss. Spores of the disease were incorporated into a feeding stimulant mixture and sprayed on plants in 30"x30"x30" cages. In the first test only about 20% of the weevils contracted the disease. Temperatures of over 100° F. and very low relative humidity during the days of the test were partially responsible for the low rate of infectivity. In the second test conducted when daytime temperatures were around 90° F., about 50% of the weevils contracted the disease. An improved formulation of feeding stimulant, Mattesia spores, agar, sugar and water, prepared as a granular material and applied to the plants, resulted in about 77% mortality in the laboratory and about 67% mortality in two field cage tests. The additional effects of reduced oviposition and transmission of disease to progeny by infected females adds to the effectiveness of the disease in population suppression.

2. Other Insects. A polyhedrosis virus controlled bollworms in field tests at Brownsville and Waco, Tex. The laboratory propagated virus was effective against both Heliothis zea and H. virescens. In three experiments on cotton at Brownsville the virus compared favorably in control with several insecticides recommended for control of the two species. A dosage rate equivalent to 100 diseased larvae per acre applied as a spray at 5-day intervals was almost as effective as a dosage of 1000 diseased larvae per acre. In an experiment at Waco the virus gave fair control but was less effective than mixtures of toxaphene and DDT or TDE.

High degree of parasitism of Heliothis sp. eggs by Trichogramma sp. was observed in late September and early October at Brownsville, Tex. Sixty-seven percent of the eggs collected on tomato plants were parasitized, 45% on corn, and 82% of a limited number collected on beans. Of the total collected from the different host plants, 56% were parasitized, with an average of 1.5 parasite adults emerging per parasitized egg.

Large parasite populations were found on Heliothis species on wild hosts at Brownsville, Tex. Early spring collections of H. zea from lettuce failed to show any parasitism, undoubtedly due to extensive use of insecticides on this crop. In the absence of insecticide use, more than 50% of the Heliothis larvae collected from wild tobacco were parasitized and in one collection of five larvae on March 1, all were parasitized. Thus the spring buildup of parasite populations on Heliothis on wild hosts may be of substantial importance for their migration to parasitize bollworms on cultivated hosts in the early season.

Geocoris pallens was a good lygus bug predator in laboratory tests at Tucson, Ariz. A 5 to 50 ratio of Geocoris to first instar lygus nymphs resulted in a 73.8% reduction of the lygus bugs. A ratio of 5 to 30 Spanogonicus albofasciatus to first instar lygus bugs nymphs resulted in a reduction of only 4.8%.

D. Insect Sterility, Attractants and Other New Approaches to Control.

1. Boll Weevil. ENT 50896 showed promise as a boll weevil chemosterilant at State College, Miss. Its general overall effectiveness and low toxicity to the weevil indicated it may be far superior to apholate, the current best material.

A mixture consisting of apholate, agar, sugar and crude feeding stimulant, showed promise in sterilizing boll weevils in laboratory tests at State College, Miss. The mixture was sprayed or dusted on seedling cotton plants. Weevils were exposed to the seedlings for five days and then fed on untreated squares for two weeks. The eggs obtained were observed for hatch. Both spray and dust treatments increased the preoviposition period, decreased the number of eggs laid, and reduced egg hatch. Complete sterility was not obtained in the preliminary tests.

In studies at State College, Miss., hempa was erratic as a male chemosterilant. Sterility was obtained at the 5% level with dips, at the 10 µg level with injection, and at the 5000 ppm level with feeding, but results could not always be reproduced. Mammalian toxicity is low with this compound.

Apholate was superior to tretamine and hempa as a chemosterilant dip for boll weevils in tests at State College, Miss. Although tretamine did better in sterilizing boll weevils it produced approximately twice as much mortality as the apholate dip. Hempa was considerably less toxic to the weevil but did very poorly in inducing sterility as a dip treatment.

Aggressive sex behavior by the female boll weevil was demonstrated in a series of tests in Florida and Mississippi. A windborne pheromone apparently secreted by the male attracted females from up to 95 feet away. Both week-old virgin females and overwintered fertile females responded. The aggressiveness of the female may extend to elaborate tactile behavior in the alerting of the male before copulation.

In studies at State College, Miss., Gossypium armourianum and G. tomentosum were lower in the boll weevil arrestant/feeding stimulant than Delta Pineland Smooth Leaf. In addition, four experimental lines, 256-1, 256-3, 256-4, and 256-8 contained less arrestant/feeding stimulant than DPSL. Cotton lines SA 189 (UA 7-21), SA 180 (Upland UA 7-1), and SA 136 (GSP 2-6-14), previously found lower than DPSL in stimulation of oviposition, also were lower than DPSL in arrestant/feeding stimulant.

A highly active boll weevil feeding and oviposition deterrent has been extracted with water from the calyx of Rose of Sharon (Hibiscus syriacus) buds at State College, Miss. This material reduces feeding on and oviposition in cotton squares treated with it. The mechanism of reception appears to be tactile as taste or preliminary probing rarely occurs on agar-water plugs containing effective levels.

2. Pink Bollworm. Metepa-sterilized males reduced pink bollworm populations in cage studies at Brownsville, Tex. Release of laboratory-reared pink bollworm moths at a rate of 180 sterile males (Metepa-treated) to 20 pairs of untreated moths (9:1 ratio) reduced the F_1 population 81% from that of the check in 1/200-acre cages with 3 treatment replicates. There was a 2.6 fold population increase in the cages with the treated insects because of high reproductive potential and favorable environment. This increase compared with a 11.8-fold increase in the cages with the untreated population, indicating that a 91.5% reduction would be required to cause a population decline. This could be obtained by increasing the ratio of sterile to normal males. Because the expected rate of increase in field populations is less than that of the caged populations, a 9:1 ratio might be sufficient to reduce a field population.

3. Other Insects. Sex lures were discovered in female moths of the bollworm, tobacco budworm, and cotton leafworm at Brownsville, Tex. Bollworm males showed no response when exposed at different times of day to the oily residue extracted with methylene chloride from the last abdominal segments and ovipositors of females. Results were similar with different solvents or when the females were crushed on filter paper. However, strong responses were obtained when males were exposed to gases emanating from the detector outlet of a gas-liquid chromatograph containing the extract. The males responded by vibrating their wings, extending their claspers, attempting to mate with each other, and flying to the source of the gases. Similar responses were obtained with a limited number of tobacco budworm moths. Cotton leafworm male moths responded to a raw extract from the females and to the gases from a chromatograph containing the extract.

E. Evaluation of Equipment for Insect Control and Detection.

1. Boll Weevil. The overall efficiency of a flail-type boll weevil infested square removal machine in tests conducted by the Agricultural Engineering Research Division at State College, Miss., was 84.2%. The machine was operated a total of 40 hours in field plot tests with only minor mechanical difficulties. When operated at a speed of 1.75 mph little plant damage was observed until the height of the plants exceeded fifty inches.

In studies at Stoneville, Miss., application of insecticides by helicopter to small cotton fields in wooded areas appeared to be a highly efficient treatment method for boll weevil control. Field population records and results of field cage tests in small isolated cotton fields treated with methyl parathion by helicopter indicated that this application method would be very desirable in areas where many small fields require treatment. It would be especially appropriate in a fall weevil control program. In field cage tests, 93.6% control of boll weevils was obtained with a swath width of 100 feet. Ninety-seven percent control was obtained with a swath width of 76 feet.

2. Bollworms. For many years more bollworm moths than tobacco budworm moths were collected in black light traps at Brownsville and Waco, Tex. This was the case even in recent years when during certain periods a high percentage of the population on cotton was the tobacco budworm. Previously it was assumed that the difference in numbers collected was due to the predominance of the bollworm in the populations. Now it appeared possible that bollworm moths might be more attracted to black light than tobacco budworm moths. Preliminary tests were conducted at Brownsville to explore this possibility. Laboratory reared 1- to 3-day old moths were released 80 feet from a black light trap in a 1/6 acre cage of cotton. Forty to 70% of the released Heliothis zea moths were collected in the trap while only 10 to 20% H. virescens were recovered. At Waco, Tex., in 1963, 2,962 tobacco budworm moths were collected in a black light trap operated from April through November. This is approximately three times the total number, 986, collected during the previous seven years (1956-1962).

F. Varietal Evaluation for Insect Resistance.

1. Boll Weevil. One hundred additional cotton lines were tested for boll weevil antibiosis with lyophilized square powder technique at State College, Miss. Eight lines produced weevils weighing less than 10 mg. (DPL Standard, 11.09 mg.). In one line 17 days were required for peak adult emergence (DPL Standard, 15.5 days). However, in 10 lines only 13 days were required for peak adult emergence. Kekchi continued to produce weevils less than 10 mg. in weight. The technique detected antibiosis present in Pima S-2 seedlings and in Gossypium thurberia and bolls for both criteria--days required for peak adult emergence and weevil weight.

In studies at State College, Miss., nonpreference for feeding and oviposition exhibited by the boll weevil for Rose of Sharon appeared to be due to the presence of a highly active water soluble anti-feeding compound in the calyx. Absence of or presence of only a low amount of an attracting substance and presence of a relatively high concentration of repelling substance appeared to be contributing factors to this non-preference. Nutrition furnished by Rose of Sharon buds and capsules was adequate for weevil development. However, adults were small (7-8 mg) and required a long development period (20 days).

Four of six cotton lines continued to show fewer boll weevil egg punctures than Delta Pine Smooth Leaf in replicated tests at State College, Miss. One of the four is a glandless stock and two are Sea Island lines. Mississippi field weevils oviposited proportionately fewer eggs, expressed in percent of those laid on DPSL, than laboratory-reared weevils on all lines except Pima S-2. Use of frozen squares tended to reduce oviposition more on S. I. Seaberry than on DPSL.

2. Bollworms. Effects of cotton plant characters are promising in control of both Heliothis virescens and H. zea in studies at Brownsville, Texas. Caged plants showed that nectariless and glabrous cottons caused a significant reduction in oviposition of H. virescens. Tests reported previously showed that response of H. zea to the nectariless and glabrous characters was very similar to that of H. virescens. Tests with pink bollworm showed a 37% reduction in mines due to the nectariless character but no significant difference between glabrous and hirsute cottons. In further laboratory tests on plant pigments, a diet containing 0.2% gossypol resulted in 78% mortality of both H. virescens and H. zea. Quercetin and rutin were more toxic to H. virescens than to H. zea. Chemical analysis of cotton leaves and squares showed free gossypol contents of different experimental strains ranging from 0.02% to 0.38% in large squares and from 0.04% to 0.5?% in leaves.

Experimental strains of cotton resistant to insects continued to show promise at Brownsville, Tex. Further work with experimental strains of cotton in cage tests confirmed previous findings that nectariless and glabrous cotton limited populations of cotton leafworm, cabbage looper, and bollworms developing on them. The nectariless character reduced oviposition compared with that occurring on plants with the usual extrafloral nectaries, and the absence of epidermal hairs was even more effective in the reduction of numbers of eggs laid. When both characters were incorporated in a single strain the reduction in numbers of eggs deposited on the plants was very striking. In randomized single-row plantings, bollworm moths laid fewer eggs on a nectariless strain and on a nectariless-glabrous strain than on any of 13 other cottons except a Pima variety. Bollworm infestations are lower on Pima than on Upland varieties probably because of a higher gossypol content. Results of laboratory tests with synthetic diets indicated that it may be possible to use the plant pigments, gossypol, quercetin and rutin in developing plant resistance to the bollworm.

At Brownsville, Tex., plantings of cotton strain 1514, which is glabrous and nectariless, in plots replicated four times in each of 4 different fields showed a marked reduction in bollworm infestation from that on commercial varieties. Although the experiment has not been completed, results of 5 inspections at 3 to 4 day intervals showed lower numbers of eggs, larvae and damaged squares on strain 1514 than on commercial varieties in all fields. A high cotton fleahopper population developed on Delta Pineland--15 in one field--but the infestation in 1514 remained low. At Waco, Tex., cotton fleahopper populations were significantly lower in 1514 plots than in plots of two commercial varieties. In another test the infestation was below the injurious level in the 1514 plots but was above this level for 3 weeks in two commercial varieties. In studies at Brownsville four experimental cottons which inhibited bollworm larval growth in greenhouse tests, also, were effective in reducing larval weight compared with larvae developing on M-8 and M-8 glandless strains in field cage tests. Larvae developing on M-9 glandless plants made the greatest gains in weight.

Gossypol content of cotton leaves influenced bollworm development in laboratory feeding tests at Tucson, Ariz. Larval mortalities after 14 days of feeding on leaves of 9 varieties or strains of cotton with different gossypol contents were compared. Mortality on a high gossypol strain (1.075%) was 83%, on an intermediate gossypol strain (0.101%) 53%, and on a low gossypol strain (0.038%) 37%. High gossypol content in cotton leaves was associated with infertile bollworm eggs. Moths produced from larvae reared on leaves of Acala 4-42-77 glandless laid all fertile eggs, whereas those from larvae reared on the genetically closely related Acala 4-42-77 glanded laid all infertile eggs. The latter, glanded strain leaves, contained 2.6 times as much gossypol as the glandless strain.

Cotton leafworm larvae fed for 9 days on square powder diets from three glandless lines and D_2723 were larger than those fed on DPSL in tests at State College, Miss. They averaged approximately 10 mg on DPSL and ranged from over 12 to over 16 mg on 3 other lines. For some unknown reason there was no survival on Hopi M5-11.

Cotton leafworm moths selected only glandless lines for oviposition in a natural infestation of a field containing 329 different lines of cotton. As larvae hatched and damage occurred, only the six glandless lines were damaged, one glandless line less than the others. A laboratory study of oviposition where only M-8 and M-8 glandless cottons were available for oviposition showed twice as many eggs oviposited on M-8 glandless. Laboratory studies with larvae showed glandless lines to rank first, third, fourth, and sixth out of nine lines in amount of leaf tissue consumed when larvae were confined on each line.

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AREA NO. 10. TOBACCO INSECTS

Problem. Insecticides that have proved effective for the control of insects that attack tobacco, particularly budworms, hornworms, flea beetles, and aphids, have resulted in undesirable residues on cured tobacco. Such residues adhere to the leaf through commercial processing into cigarettes and some have been found in the main-stream of smoke from commercial cigarettes. There is, therefore, need for the development of effective methods of controlling insect pests of tobacco that will not lead to insecticide residues in cigarettes or other manufactured tobacco products. This would include more intensive research on lures, light traps, sterilization, and other new approaches to control; better utilization of predators, parasites, and diseases of tobacco insects; evaluation of tobacco varieties which resist insect attack; and research for insecticides that leave no residue.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing program involving basic and applied research on tobacco insects to develop effective control methods that will not lead to insecticide residues in cigarettes or other manufactured tobacco products. The program is cooperative with State and Federal entomologists, chemists, agronomists, and agricultural engineers in the States where research is underway, and with the tobacco industry. Studies are conducted at Oxford, N. C.; Florence, S. C.; and Quincy, Fla. Work is under contract with Kentucky, North Carolina, and South Carolina Agricultural Experiment Stations, and with the Virginia Polytechnic Institute.

The Federal scientific effort devoted to research in this area totals 5.9 professional man-years. Of this number, 1.1 is devoted to basic biology, physiology, and nutrition; 0.6 to insecticidal and cultural control; 0.1 to insecticide residue determinations; 0.8 to biological control; 2.3 to insect sterility, attractants, and other new approaches to control; 0.0 to evaluation of equipment for insect detection and control; and 0.7 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The tobacco-producing States have an active research program on tobacco insects and their control. Biological research places emphasis on seasonal history and behavior of injurious insects. Much of this work consists of evaluating the effects of environmental conditions throughout the year on population dynamics and rearing the insects in the field and laboratory. For example, in the tobacco hornworm the winter survival, length of life and factors inducing and terminating diapause are being studied. The accumulation of data on abundance and its relation to climatic factors may make it possible to predict the severity of infestations of this insect.

New insecticides, particularly those believed to be heat degraded or metabolized are being screened to determine their efficiency in controlling tobacco insects. Those materials which appear to be biologically promising are placed in advanced testing programs. Coincidentally, the fate of the residue from application through curing, aging, and smoking is studied. New application methods, particularly those which might decrease residues, are evaluated. Attempts are being made to utilize parasites, predators and disease organisms more effectively. Cultural controls under investigation include influences of crop rotation and fertilizer application on the kinds and numbers of insect pests that attack tobacco.

Research is in progress to isolate the female attractant from the hornworm moth and use it or other baits to lure the moths to traps.

Plant resistance studies entailing screening of varieties and foreign introductions are being conducted to locate factors conferring resistance to specific pests. Susceptibility to infestation is measured by comparing the reproduction of the pest involved on each variety, the relative tolerance of the plants to insect attack and general agronomic characteristics. Where resistance is observed, backcrosses and selections are made to convey the responsible factor to adapted varieties. Biochemical studies are performed to determine the chemical nature of the factor and its influences on the pest involved.

There are 5.9 man-years dedicated to research on tobacco insects by the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology and Nutrition

In North and South Carolina up to one third of the budworms attacking tobacco in the spring are corn earworms. In studies in Florida in 1962 and 1963 this species was not found on tobacco until after harvest in August. Early harvest of tobacco in Florida allows time for two broods of hornworms on sucker growth. In 1963 priming was completed in all fields the first week of August but suckers were present until the plants dried up in late September.

Light trap catches of tobacco hornworm moths on St. Croix, Virgin Islands, show a seasonal pattern resembling that in Florida. The numbers caught were 15 to 31 per month from April to the middle of December and one or two from December through March.

Two methods have been developed to collect large numbers of hornworms. At Florence, S. C., large fifth instar larvae were collected from tobacco fields, then fed tobacco plants in racks, and finally allowed to pupate in loose soil over wire screening. Out of 90 thousand larvae collected, about 36% were recovered as pupae. These were stored in shredded paper in cardboard

boxes in an unheated building for the winter and about 80% survived. At Oxford, N. C., moths were allowed to oviposit on cut plants and the larvae reared on cut tobacco or released in the field. The large fifth instars were collected and placed in wooden cells and kept at a high humidity. About 80-90% of these larvae were recovered as normal pupae.

Rearing studies conducted with various diets for the tobacco budworm indicate that the larvae must be isolated. A single individual can be reared in about 1 square inch of space on less than 5 grams of food. Labor in egging the moths was greatly reduced by using a cage with walls made of paper towels. The towels are drawn through the egging chamber to collect the eggs.

B. Insecticidal and Cultural Control

In field experiments at Florence, S. C., the two species of wireworms that are serious pests of newly set tobacco plants and have become resistant to most of the chlorinated hydrocarbon insecticides were not effectively controlled with parathion during 1963. This is the first season that parathion has failed to give excellent control at the recommended dosages.

At Quincy, Fla., the practice of applying chlorinated hydrocarbon insecticides plus parathion once or twice each week to shade tobacco results in very high residues on the wrapper leaf of cigars. To reduce these high residues, an experiment was set up in which the shade was planted with insect-free plants. Granular Di-Syston was applied as a preplant treatment at 4 lb. per acre for aphids. Budworms and cabbage loopers were hand picked each week. No insecticides were necessary until 5 primings had been harvested. At that time the plants were pushing up the top of the shade cloth even though it had been raised 18 inches, and budworms laid eggs on the plants through the top cloth. Two applications of endosulfan and parathion controlled these insects. A light trap inside the shade caught small numbers of budworms, corn earworms, cabbage loopers and cutworm moths.

Di-Syston at 4 lb. per acre increased the yield by about 9%. There was no apparent effect on rootknot or black shank, but the index of coarse root disease was reduced 64 to 55 according to the cooperating Florida State plant pathologist.

Cigars made from shade tobacco treated with Zectran, Di-Syston, Niagara 9203, Kelthane, and Bayer 44646 and taste tested by the American Tobacco Company were equally as good as the untreated check.

C. Insecticide Residue Determinations

Preliminary results obtained by chemists indicate that residues of DDT and endrin were higher on commercial grown shade tobacco in 1963 than they were in 1962.

D. Biological Control

At Quincy, Fla., tests were made with weekly applications of the bacterium Bacillus thuringiensis and a Heliothis virus for the control of all insects on sun tobacco without use of insecticides. The virus alone was slow in killing the tobacco budworm and gave only about 50% reduction in damage; Bacillus alone or with the virus reduced damage 75 to 80% and gave reasonably good control.

E. Insect Sterility, Attractants, and Other New Approaches to Control

At Florence, S. C., the crude extract of sex attractant which was obtained from virgin female tobacco hornworm moths was tested in field trap cages. The numbers of moths captured during one night were 18, 31, and 40 for 10, 20, and 40 female equivalents, respectively. During the early part of the season when hornworm populations were low, traps were baited with live virgin females. One female attracted as many as 38 males in 7 nights. A few were not attractive, but most of them attracted 1 to 8 males per night. Several attracted 9 to 12 and 1 attracted 17 in one night. At the same time a trap baited with 20 female equivalents of extracted material captured 6 to 20 males per night. Crude extracts were effective for only one night.

At Oxford, N. C., virgin females of the tobacco budworm, caged in a modified gypsy moth trap, attracted males. Traps baited with either extracts of whole virgin females or hexane extracts of the last two abdominal segments also caught males and were effective up to nine days when the extracts were kept in the refrigerator during the daylight hours. The maximum male response occurred just prior to dawn.

A large light trap experiment using 3 traps per square mile over 113 square miles has been conducted at Oxford, N. C. for 3 years. In 1962 the indicated reduction in hornworm numbers was about 60%. In September of that year, tobacco growers reduced the acreage of tobacco stalks on which overwintering populations of hornworms and budworms are produced by about 50%. In 1963 in a continuation of the light trap experiment, the number of hornworm eggs on tobacco in the lighted area was reduced 83% over that in the check or unlighted area. The number of insecticide applications applied by growers in the light trap area was reduced by about 90%. In September a campaign to get all of the stalks cut was more than 90% successful. Spring populations in 1964 were very low, but the indicated control was about the same as 1963.

In the above light trap area there was also some reduction in the tobacco budworm and corn earworm populations. Where traps were located in cornfields the number of ears infested by the corn earworm was reduced about 80% within 50 feet of the trap, but there was no effect at 300 feet. However, there was a general population reduction on sweet corn of about 20% within the trapped area.

Populations of other species of large moths were also reduced in the light trap area. The Plebian Sphinx was reduced from 40 per light trap outside the lighted area to 6 per trap inside, and the Luna moth from 20 per trap outside to 4 inside.

Male hornworm pupae subjected to varying dosages of gamma radiation were not completely sterilized up to 80 kr. Almost all of the pupae died when treated with 15 to 40 kr. at 7 to 15 days before emergence, but there was no significant increase in mortality or crippling between 5 and 80 kr., when the pupae were treated 8 hours to 2 days before moth emergence.

Experiments with chemosterilants showed that topical treatments of 360 ug of tepa will sterilize male hornworm moths. When males caught in light traps were marked sterilized and released, they lived almost as long as untreated males, but the life of laboratory-reared males released at the same time was shortened as indicated by recapture data.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

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AREA NO. 11. SUGARCANE AND SUGARBEET INSECTS

Problem. Control of insects on sugarcane and sugarbeets is essential because of destructive plant diseases spread by insects and damage caused by insects feeding on the roots and foliage. Adequate control often requires use of insecticides with special care to avoid contamination of the harvested product with undesirable residues. Safe effective methods of control are especially needed for the sugarcane borer, the sugarbeet root maggot, and the beet webworm. Sugarcane mosaic has become more important in recent years and information on insect vectors of this disease is needed. Beet yellows and associated western yellows virus diseases of sugarbeets continue to threaten the sugarbeet industry. Emergency chemical control measures for the aphid vectors of the viruses of these diseases are urgently needed. Development of suitable control measures is handicapped by lack of adequate knowledge of the identity and ecology of the insect vectors and plant reservoirs of the two viruses. For long-range solutions to these problems, further investigations should be undertaken to find effective parasites and predators of sugar-crop pests and to develop varieties of sugarcane and sugarbeet that are resistant to insect attack. The usefulness of destruction of alternate host plants, and new approaches to insect control, such as the male sterility technique and attractants, should also be investigated. Research should aim to develop control methods without objectionable features. Key insect pests that require heavy use of insecticides for their control and thereby make the natural control of other pests on the same crops difficult are special problems that should receive emphasis in the search for nonchemical methods of control.

USDA AND COOPERATIVE PROGRAMS

The Department has a continuing long-range program involving basic and applied research on the insect problems of sugarcane and sugarbeet directed toward developing efficient and economical control methods. This program is cooperative with State and Federal entomologists, agronomists, and chemists in the States where research is underway, and with industry. Studies on sugarcane insects are conducted at Houma, La., Canal Point, Fla., and Mayaguez, Puerto Rico, and on sugarbeet insects at Mesa, Ariz., Twin Falls, Idaho, Logan, Utah, and Yakima, Wash.

The Federal scientific effort devoted to research in this area totals 9.0 professional man-years. Of this number, 1.0 man-year is devoted to basic biology, physiology and nutrition; 2.1 to insecticidal control; 0.8 to insecticide residue determinations; 1.1 to biological control; 1.0 to insect sterility, attractants and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; 0.6 to varietal evaluation for insect resistance; 1.7 to insect vectors of diseases; and 0.6 to program leadership.

In addition, natural enemies of the sugarcane borer in India are being studied under a P. L. 480 research grant Project A7-ENT-1 by the Commonwealth Institute of Biological Control, Bangalore, India. Parasites and predators found effective for borer control will be made available for use in the United States.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in the States on insects affecting sugar production is concerned with disease transmission, biological studies and control.

On sugarbeets, studies are in progress on both curly top and yellows disease. Fields and desert breeding grounds are sampled to determine the population levels of insect vectors. The influence of date of planting, plant resistance, and other control practices such as foliar and seed applications of systemic insecticides are being evaluated for their effectiveness in reducing disease incidence.

The ecology of other insect pests of sugarbeets is also under investigation. Variations in temperature and other natural phenomena are being correlated with seasonal development. Records are obtained of overwintering sites, time of appearance in the spring, oviposition, pupation, emergence of late generations, host preferences, and the effects of various hosts on development.

Similar biological studies are being conducted on insect pests of sugarcane. In addition, insecticides and other agents are being evaluated for their effectiveness in control. The identity and importance of natural enemies and the effects of insecticides on beneficial species is being determined. Variations in responses of plants to insect attack are also under investigation. Survey methods are being developed to obtain a more accurate estimate of losses caused by insect attack.

Scientists are investigating the possibilities of control of the sugarcane borer by radiation. Mass rearing methods are being developed and various life stages of the insect subjected to gamma radiation to determine the levels necessary for sterilization. Light of different wave lengths and chemicals are being investigated to determine their usefulness as attractants to the sterilization source.

In all, 4.3 man-years are dedicated to research on insects affecting sugar production in the States.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Sugarcane Insects. The annual 1963 harvesttime survey to determine sugarcane borer infestation and crop loss in Louisiana showed 12% of the joints of sugarcane bored, with an estimated crop loss of 9%. The

first-generation infestation in 1964 showed an estimated average of 549 borer-killed plants per acre. This average is slightly over 100% higher than the 1963 average and 14 times higher than the 1962 average. In Florida the sugarcane borer is a much greater problem in the newly expanded areas of sugarcane production than in old fields around Lake Okeechobee. In Puerto Rico the sugarcane borer continues to be the major pest of sugarcane with 6 to 9% of the joints bored, depending on locality. The yellow sugarcane aphid, Sipha flava, is increasing in Puerto Rico, encouraged by a major drought which occurred over parts of the sugarcane areas during most of the first half of 1964.

Laboratory studies conducted in Puerto Rico indicate that light intensities of less than 0.04 foot candles are necessary to initiate mating of the sugarcane borer. Under caged conditions sex ratios of 2:1 (male-female) resulted in the highest mating success with maximum viable egg production. Mating is usually accomplished within one hour, and one male is capable of successfully inseminating at least 4 females. Fully successful matings result in nearly 100% hatch when environmental conditions are satisfactory.

A new method of preparing sugarcane borer diets has resulted in a substantial improvement over diets previously considered satisfactory. Killing of sugarcane tissues with ether fumes apparently prevents masking of gustatory stimuli attractive to the sugarcane borer and borers feed immediately and energetically upon sugarcane treated in this way. Other diets tested were rejected in favor of the new diet. Control of contamination is essential in the mass rearing of the sugarcane borer. Mercuric chloride-soaked cotton plugs for vials containing single larvae, control externally introduced fungi and bacteria completely. Buffer systems in dietary media helped but have failed to suppress consistently and completely bacteria associated with the food itself.

2. Sugarbeet Insects. Studies of the beet webworm in southern Idaho showed that such weeds as redscale, Russian thistle, and lambsquarters are preferred food plants. The first 1 or 2 broods of the webworm develop on these weeds. Sugarbeets are subject to damage by the second and third broods, depending upon the season. Damage to sugarbeets is not correlated with numbers of moths in flight.

The leaf-mining larvae of the ephydrid fly, Psilopa leucostoma were first found infesting leaves of sugarbeet in the United States at Walla Walla, Wash., in 1962. The insect spread to the Yakima Valley in 1963 and was found throughout the Columbia Basin of eastern Washington in the spring of 1964. It appears later in the season and attacks leaves in greater numbers--20 to 40 or more small mines per leaf--than the spinach leafminer (Pegomya hyoscyami). The insect was controlled with repeated applications of demeton or phosphamidon sprays.

In Washington biweekly counts of the winged-migrant forms of the green peach aphid caught in two yellowwater-trap pans per sugarbeet field correctly forecast the time of aphid colonization and aphid population changes on the crop.

The sagebrush defoliator (Aroga websteri) described in 1932 from moths collected in eastern Washington some years earlier, was reported to have defoliated and severely damaged between 10,000,000 and 12,000,000 acres of sagebrush in the West in 1963. Removal of sagebrush would allow the growth of annual weeds suitable for breeding large numbers of the beet leafhopper.

B. Insecticidal and Cultural Control

1. Sugarcane Insects. In tests conducted in Louisiana in 1963, Guthion, carbaryl, and endosulfan controlled the sugarcane borer. Endrin and ryania are the currently recommended insecticides for the borer. Insecticide applications are recommended only after joints have begun to form, and whenever 5% or more of the stalks are infested with young larvae feeding in or under the leaf sheaths and which have not yet bored into the stalks.

In 1963 field tests in August, planted cane in Louisiana, endosulfan, carbaryl, Cl-47031, Cl-47470, 10B Thuricide, Cryolite BTB, Guthion, endrin, diazinon, Methyl-Ethyl Guthion, Bayer 25141, and Bayer 38156, were tested for control of the sugarcane borer. Bayer 38156 and 25141 were applied as foliar sprays, while all the other materials were applied in the granular form. Cl-47031 and Cl-47470 were each applied one time, while all the other materials, with the exception of Bayer 25141, were applied 3 times at biweekly intervals. Bayer 25141 exhibited pronounced phytotoxicity and the use of this material was discontinued after one application. All the insecticides tested gave significant reductions in numbers of deadhearts. Control ranged from 99% for endrin and diazinon to 65% for Cryolite BTB. Cl-47470, a systemic insecticide, showed promise, giving 88% control with one application. Endosulfan, carbaryl, Guthion, Methyl-Ethyl Guthion, and Bayer 38156, were highly effective. Cl-47031, 10B Thuricide, and Cryolite BTB gave 65 to 70% control.

In a small-plot replicated test in Louisiana comparing 19 inseciticides for control of small soil arthropods associated with root rot diseases of sugarcane, chlordane at 2 pounds per acre was the most effective. Chlordane-treated plots produced 85% more cane and 98% more sugar than the check. Plots treated with other insecticides had significant increases in sugar, as follows: Telodrin - 75%, phorate - 67%, Kepone - 65%, V-C 13 - 64%, Bayer 25141 - 64%, and Bayer 37344 - 62%. Plots treated with Ciodrin, fenthion, and T. D. 183 gave less sugar than the 1,768 pounds per acre for the control.

2. Sugarbeet Insects. At Worland, Wyo., and Grand Junction, Colo., 1 or 2 ounces of phorate per acre in pelleted sugarbeet seed decreased beet leafhopper populations and reduced curly top by 49%. Yield was increased approximately 1 ton per acre and percent sucrose was increased, resulting in a net gain of 425 pounds of sugar per acre. At 2 ounces per acre in pelleted seed, phorate also reduced flea beetle damage to the cotyledons

and first 2 pairs of leaves 86% and leafminer damage 87%. At Logan, Utah, symphylans were controlled and stands of sugarbeets improved 25% by the use of pelleted seed containing either 1.5 ounces of Di-Syston or 3 ounces of V-C 13 per acre.

Seven new materials tested in the laboratory at Twin Falls, Idaho, as slurry treatments on sugarbeet seed showed promise as a control for the beet leafhopper and for prevention of curly top. However, in field tests all but Union Carbide 21119 were phytotoxic. Parathion and diazinon were recommended for the first time in 1964 for the control of wireworms, based on field tests in 1963. They are applied as granules broadcast and worked into the soil before planting. Two applications of phorate in a spray at a dosage of 1 pound per acre per application to small sugarbeet plants gave control of the green peach aphid superior to that of 2 applications of granular phorate. At harvesttime 18% of the beet plants that received 2 spray applications showed beet western yellows symptoms as compared to 52% in the nontreated check plots.

Laboratory tests against the beet webworm in Idaho revealed many promising new insecticides. Of 52 materials tested, 25 gave better than 95% control when larvae were caged on potted beet plants 1 day after spraying, which was as good as the DDT used as a standard. Twenty-three of the materials gave as good control as DDT one week after treatment and 15 gave very good control with as little as 0.25 pound per acre. Early applications of emulsion sprays of dimethoate at 1.5 pounds per acre to sugarbeets grown for seed in Utah reduced Lygus populations 58% and increased seed viability to 94% compared to 89% in untreated plots and 91% where toxaphene was used later in the season.

C. Insecticide Residue Determinations

1. At Yakima, Wash., numerous chemical analyses were made of samples of sugarbeets from experimental plots in Washington and Idaho for insecticide residues. These studies showed that persistent insecticides such as DDT, aldrin, dieldrin, and endrin cannot be used on sugarbeet foliage, soil, or seed without danger of contamination of the raw roots and dehydrated pulp with undesirable residues. On the basis of these studies it has been necessary to discontinue all recommendations for the use of DDT, aldrin, dieldrin, and endrin for the control of sugarbeet insects. The most outstanding findings were that 1/2 pound of dieldrin on 100 pounds of seed is sufficient to cause significant dieldrin residues in the raw sugarbeet roots grown from the treated seed. Also, the use of 5 pounds of aldrin per acre in the soil to control wireworms on potato one year was sufficient to cause excess residues in sugarbeets grown in the soil the following year. The work also showed that residues of these insecticides in the raw sugarbeets is not lost in processing the roots but is concentrated in the dehydrated pulp which is used in cattle feed.

A dimethoate emulsion concentrate spray (0.44 lb. dimethoate per acre in 9 gallons of water), applied with fixed-wing aircraft to sugarbeets in Washington infested with the green peach aphid, drifted to alfalfa due to an 8-10 m.p.h. cross wind. Residues were recovered on alfalfa at least 340 feet from the end of the spray plot 1 day after treatment and 1.4 ppm dimethoate was recovered from hay 110 feet from the plot 5 days after treatment.

D. Biological Control

1. Sugarcane Insects. The Cuban fly parasite of the sugarcane borer survived the two coldest successive winters of the century in Louisiana. In 1962 no parasites were recovered. In 1963 parasitization was 18%, the highest recorded since the conclusion of the introduction program in 1959. In June 1964, the parasite was recovered on several plantations in southeast Louisiana where it has become established. In one field on a plantation where the last releases were made in 1956, parasitization of first-generation borers was 8%. In Puerto Rico parasitization was above 55% during much of the year. Collections of borer eggs during the fall of 1963 in fields of summer-planted sugarcane in Louisiana showed an average parasitism of 43% by the native egg parasite Trichogramma. The 1961 and 1962 fall parasitism averaged 39 and 32% respectively. Parasitism usually averages about 75%.

Three parasites imported from India in connection with P.L. 480 project A7-ENT-1 are being tested on the sugarcane borer in Florida. One is an ichneumonid, Centeterus alternecoloratus, that parasitizes the prepupal and pupal stages of borers in India. The other two, a braconid, Rhaconotus signipennis, and a tachinid, Sturmiopsis sp., parasitize fourth and fifth instar borers.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sugarcane Insects. Chemosterilants tested in the laboratory in Puerto Rico caused heavy mortality of the sugarcane borer. Sterilization by means of heat was unsatisfactory because mean lethal and mean sterilization temperatures are unduly close to one another.

Work on sex attraction of the sugarcane borer has been initiated in Puerto Rico. Attractant extracts were made using methylene chloride at 5cc, 2cc, and 1cc per female abdomen. Extracts were placed on filter paper in a venturi-equipped wind device built for attractant studies. Courtship behavior did not start until light levels were reduced below 0.04 foot candles. Previous study with female borer moths resulted in similar conclusions.

F. Varietal Evaluation for Insect Resistance

1. Sugarcane Insects. In Louisiana, 26 new parent varieties of sugarcane with some degree of resistance or tolerance to the sugarcane borer were recommended to sugarcane breeders for use in developing new commercial varieties. Of 358 sugarcane varieties tested in hand infested plots for borer resistance, 27% had fewer joints bored, and 31% produced more sugar than commercial variety C. P. 36-105 used as a standard. Twenty-two agronomically promising unreleased varieties were grown in a replicated test in Louisiana under each of two controlled levels of borer infestation. Five showed a marked degree of tolerance. The 5 varieties, C. P.'s 58-15, 58-48, 58-51, 59-56, and 59-29 were among those showing the greatest tolerance the previous year. Other varieties showing the least loss in sugar per acre were C. P. 57-98, C. P. 58-2, L. 56-25, C. P. 58-43, C. P. 59-53, and L. 56-11. The first 3 of these were among the most tolerant in 1962. In terms of loss of pounds of sugar per ton of cane, varieties C. P. 59-62, C. P. 59-29, C. P. 58-48, C. P. 59-53, and C. P. 58-15, showed the least loss in 1963. All but the last of these varieties also showed a relatively small loss in 1962. Of 369 varieties assigned C. P. and L. numbers in 1963 that were examined for borer infestation and injury, only 9 appeared to be resistant to the borer. Thirty-four appeared to be very susceptible and the rest moderate to average in susceptibility.

G. Insect Vectors of Diseases

1. Sugarcane Insects. Spring populations of sugarcane mosaic vectors, the corn leaf aphid (Rhopalosiphon maidis), the rusty plum aphid (Hysteroneura setariae), and the sowthistle aphids (Amphorophora sonchi and Dactynotus ambrosiae), were higher in 1963 than in the 2 previous years. These species were the most generally distributed of the 7 known vectors of sugarcane mosaic. Studies were continued to determine the feasibility of sugarcane mosaic control by means of chemical control of the vectors. In a 22-acre block of 2 susceptible varieties of sugarcane, 4 biweekly applications of demeton in the fall and 5 in the spring reduced mosaic spread by 30% in one variety that had been planted the previous summer, while in the other, a fall-planted variety in which the chemical was similarly applied in the spring but with only 2 fall applications, disease infection was reduced by 64%.

Transmission studies showed that the brick-red sowthistle aphid, which appears to be the most efficient vector of the sugarcane mosaic virus, can become viruliferous after feeding for 5 minutes and transmit the virus within a 5-minute period. The insect can transmit the virus to more than one plant although it remains viruliferous for only a short time. These studies indicate that the sugarcane mosaic virus is nonpersistent in that a latent period in the vector before being transmitted is not necessary. Viruliferous brick-red sowthistle aphids were able to transmit the virus to healthy sugarcane plants treated 24 hours previously with demeton before being killed by exposure on the treated plants.

2. Sugarbeet Insects. At Mesa, Ariz., field-plot experiments showed that high fertility reduced damage to the beet seed crop caused by infestations of green peach aphids carrying viruses of either beet yellows or beet western yellows, or both. Plots infested with aphids carrying both yellows viruses yielded 3636 pounds of seed per acre with average fertility and 4394 pounds with additional fertilizer, a significant increase of 21%. Plots not infested with yellows-infective aphids produced 4282 pounds of seed under average fertility conditions and 4740 pounds with additional fertilizer. The viability of the seed was unaffected by the yellows viruses. Previous work showed the value of aphid control under yellows conditions. These data indicate the value of maintaining high fertility if the sugarbeet seed crop is likely to be subjected to infestations of yellows-infective green peach aphids.

Small and cull sugarbeets left in the field at harvest or in tare piles at beet-receiving stations provided an overwintering source of aphid-borne beet and beet western yellows viruses in eastern Washington. Because the mild winter of 1963-4 these overwintering virus sources and the green peach aphid were unusually abundant. The most severe beet western yellows infection was not found in fields where the greatest populations of the green peach aphid had developed but in fields with irregular terrain on the leeward side of rolling hills, or in ravines, where viruliferous green peach aphids settled out of the prevailing west winds.

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AREA NO. 12. ORNAMENTAL SHRUB, FLOWER, AND TURF INSECTS

Problem. Ornamental shrubs, flowers, and turf are damaged by the feeding of a variety of insects and mites. They are also damaged by a variety of diseases spread by insects. More effective and safer control measures are needed for many of these pests. Knowledge of the basic distribution of insect pests of these plants and information on their biology are required to provide a sound basis for the development of practical, effective, and safe control measures. Insecticidal and cultural methods of control that will not affect adversely the growing plants or natural enemies of the pests or result in objectionable residues are needed. The nature and cause of resistant strains of insects and mites and means of overcoming or preventing their resistance to insecticides require continuing investigation. The role and use of biological control agents should be more fully explored and efforts made to integrate biological control with insecticidal and cultural control methods. Use of controlled light and other physical factors as possible means of controlling greenhouse pests should be studied. Increased emphasis should be placed on the search for insect attractants, chemosterilants, and growth or reproduction-affecting substances.

USDA AND COOPERATIVE PROGRAM

The Department has a long-range program of basic and applied research on insect and mite pests of ornamental shrubs and flowers at Beltsville, Md., Farmingdale, N. Y., and Sumner, Wash., in cooperation with State Experiment Stations of Maryland, New York, Oregon, and Washington, and with the Crops Research Division; and on turf insects at Moorestown, N. J., and Geneva, N. Y., in cooperation with the State Experiment Stations of New Jersey, New York, and Michigan, and the Northern Utilization Research and Development, Plant Pest Control, and Agricultural Engineering Research Divisions of ARS.

The Federal scientific effort devoted to research in this area totals 6.0 professional man-years. Of this 0.4 man-year is devoted to basic biology and nutrition; 1.8 to insecticidal control; 1.2 to biological control; 1.0 to insect sterility, attractants, and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; 0.4 to insect vectors of diseases; 0.6 to insect control treatments for commodities regulated by plant quarantine; and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The research program in the States on insects affecting ornamental shrubs, flowers and turf is providing valuable information. Surveys are being conducted to determine the occurrence and abundance of insects and mites and their natural enemies. Investigations are underway to evaluate the extent and amount of damage caused by injurious species. Studies of seasonal life histories form a basis for developing practical control measures. Insects

are reared in the field and collected for laboratory observation on the duration of life cycles in relation to temperature and other environmental factors. This information is used to determine which types of control methods would be used for most satisfactory results.

Principal emphasis is placed on chemical controls due to (1) the sporadic nature of insect and mite attacks on many ornamental plants; (2) the need for extremely effective control in nurseries to prevent dissemination of pests; and (3) the comparatively permanent nature of plantings of most ornamentals and turf grass which prevents the use of many cultural control methods. As new chemicals become available, they are evaluated for safety, phytotoxicity and effectiveness in controlling injurious insects. Various formulations, schedules, concentrations and application rates are tested. Recently, increasing emphasis is being placed on the use of systemic insecticides on ornamentals because of their greater ease of application, and reduced environmental toxicity hazard.

Resistance of certain mite species to control chemicals also is being studied. The incidence and degree of resistance is being determined, and the morphology and physiology of affected strains of mites studied to identify the factors responsible. Biochemical methods are being employed to determine differences in physiological systems not observable in behavior and morphological studies.

The State Stations are devoting 16.0 man-years to the research in this area.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Insect Pests of Ornamentals. At Sumner, Wash., the orange tortrix was successfully reared in numbers on an artificial diet. Development required 51 days from egg to adult at temperatures ranging from 65 to 80° F. and 14 hours of artificial light. The egg stage required 9 days, the larval stage 33, the prepupal stage 2, and the pupal stage 9. The female lays an average of 224 eggs the night following mating. Mating usually takes place between midnight and 6 a.m. and was never observed without at least 2 hours of darkness. Females taken from the mating and oviposition cages containing 2 males per female contained as many as 3 spermatophores. The last one received by the female was much smaller than the previous two. In one instance, the third spermatophore actually was partially outside the bursa copulatrix.

Possibility of mass rearing the omnivorous leaf roller was demonstrated at Beltsville by the successful rearing of larvae on the alfalfa meal-vitamin-agar medium as used for red-banded leaf roller at the Vincennes, Ind., laboratory. Of newly hatched larvae placed in jelly dishes of medium, 80% reached maturity. Presence of a female attractant in this species was indicated by males coming to screened cages containing a virgin female or to plastic dishes in which virgins were confined.

At Farmingdale, N. Y., as many winged aphids were captured in 10 yellow pans of water spaced 1 foot apart as when spaced 8 feet apart. This finding supports previous evidence that aphids are attracted to yellow from only a very short distance. More aphids were caught per unit yellow area on sticky board traps than in the water-pan traps.

B. Insecticidal and Cultural Control

1. Insects of Ornamentals. In greenhouse tests at Farmingdale, N. Y., and Beltsville, Md., dichlorvos at 0.5 g/1000 f^3 applied with hand-carried electric mist sprayers killed green peach aphid and whitefly adults; at 1 g/1000 f^3 it killed resistant spider mites and citrus mealybugs. About 200 kinds and varieties of ornamental and vegetable plants were treated without injury except for slight specking on one petunia variety and on Shasta chrysanthemum. Dichlorvos residues on greenhouse tomatoes from mist spray applications and from aerosols were similar. Preliminary tests indicate that electric mist sprayers offer promise for use with concentrate sprays in greenhouses.

In pot drench tests with systemic insecticides at Sumner, Wash., on iris in greenhouse benches, phorate, dimethoate, and Meta Systox-R at 1/4 cupful per 4-in. pot of a 1 lb/100 gal. solution gave complete control of the tulip bulb aphid for the entire forcing period. Meta Systox-R applied in the same manner also gave complete control for 120 days of the western lily aphid on greenhouse forced Ace and Croft lilies.

At Beltsville, binapacryl and Pentac residues in laboratory tests were approximately equal in persistency against resistant spider mites and Morestan was less persistent. In addition Morestan was extremely toxic to lima beans.

2. Japanese beetle. The search was continued at Moorestown, N. J., for new insecticides that could be substituted for the chlorinated hydrocarbons for control of Japanese beetle grubs in soil. Carbaryl at the rate of 10 pounds per acre was effective for 90 days against newly hatched grubs.

Soil samples from areas in eastern Illinois treated with granular aldrin, dieldrin, or heptachlor for control of Japanese beetle larvae were analyzed. Dieldrin appears to be the most persistent of these insecticides with 10 to 18% of the original amount remaining in the soil after 9 years. From aldrin treatments 5 to 23% of aldrin plus dieldrin remained after 3 years. Heptachlor-treated plots showed 2 to 35% heptachlor plus heptachlor epoxide remaining after 3 years.

C. Biological Control

Japanese beetle. During 1963 a survey of the status of the milky disease bacteria was made in 11 counties of New Jersey where the pathogen had been colonized during 1939-1941. The milky disease bacteria were found in all

grasslands where the pathogen had been colonized and they had spread to other grasslands and cultivated fields within 2 miles of the colonization sites.

D. Insect Sterility, Attractants, and Other New Approaches to Control

1. Insects on Ornamentals. At Beltsville, Md., over 99% of adult omnivorous leaf roller females were rendered sterile by exposure to gamma radiation at a dosage of 16 kr. Thirty-two kr. were required to sterilize adult males to the same extent.

A unique nonchemical method was used experimentally to repel flying aphids and prevent them from spreading plant disease. The number of aphids flying to gladiolus plots was reduced 96% by aluminum sheets that were spread between the rows of plants and around the borders of the plots in tests made in New York in cooperation with Cornell University. Indian ironweed, a potential oilseed crop, was protected in a similar manner in experiments conducted in Maryland. Aluminum powder sprays on the plants were about as effective as aluminum foil but lacked persistence.

2. Japanese Beetle. At Moorestown, N. J., successive matings of female Japanese beetle with fertile and sterile males resulted in some batches of eggs that developed normally and others that failed to hatch. Apholate, metepa, and tepa sterilized adult beetles but were ineffective when applied to immature stages.

E. Evaluation of Equipment for Insect Detection and Control

The investigation of blacklight lamps as lures for the adult European chafer confirmed that traps with 6-watt blacklight lamps operated in competition with those with 15-watt lamps captured only about one-half as many chafers as did the traps with the higher wattage, but when operated independently, the efficiency of the 6-watt trap in capturing chafers approached that of the 15-watt trap.

The blacklight fluorescent lamps manufactured now by the General Electric Company have a new phosphor referred to as the Philip's phosphor. This produces a peak radiation at a slightly longer wave length than the conventional phosphor, but the outstanding difference is the much greater energy output toward the blue in the 4,000 Angstrom region. Tests demonstrated that blacklight lamps equipped with either of these phosphors were equally attractive to chafers.

F. Insect Vectors of Diseases

1. Insects of Ornamentals. In cooperative tests with Crops Research Division at Beltsville lily rosette was transmitted by the melon aphid for at least 12 days after removal from source virus. It should therefore be classed among the persistent viruses. Tests using whitefly, thrips, and

aphids to transmit yellow spot virus of geraniums have produced negative results.

Pronounced green and yellow mottle, large ringspots and chevron patterns in amaryllis leaves, suspected of being symptoms of a virus infection, have been duplicated in healthy seedling amaryllis with inoculations of sap and in transmission tests with the green peach aphid. The virus produced cucumber mosaic virus disease when transmitted mechanically or with aphids to tobacco and other indicator plants. Identification of the malady in amaryllis as a virus disease and determination of its mode of transmission have furnished a basis for making control recommendations to commercial amaryllis growers and home owners.

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